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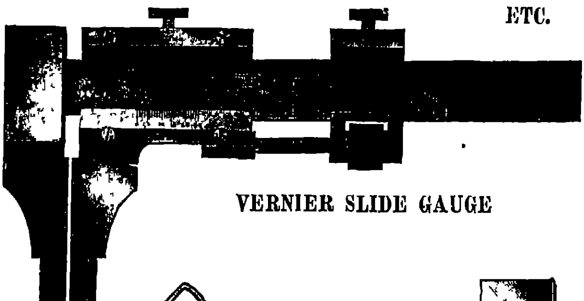

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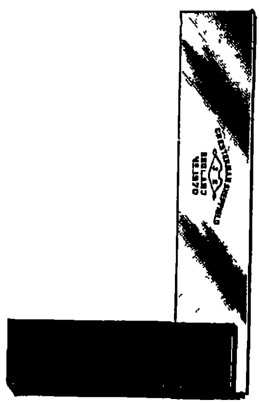

ENGINEERS' TRY SQUARE

ORKSHOP GAUGES AND EASURING APPLIANCES

AN INTRODUCTORY TREATISE ON THE RINCIPAL MEASUREMENTS REQUIRED AND THE INSTRUMENTS USED IN WORKSHOP PRACTICE

FOR APPRENTICES AND STUDENTS

BY

LOUIS BURN

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PREFACE

The introduction of machinery, to supplement or replace manual labour, is one of the great romances of the nineteenth century; and the consequent enormous expansion of trade and commerce is very aptly termed the Industrial Revolution. Labour resisted its introduction in the first instance, due to an entire misconception as to the true place of machinery in a world ever seeking to develop its trade and commerce, but to-day industry is little hampered by the antagonism of labour as regards mechanical contrivances. The mechanic of to-day looks upon machinery as a means of adding materially to his wage-earning capacity and as an appliance creating a demand for labour, whereas originally he regarded the machine as an invention which would reduce the demand for, and the value of labour in the world's markets.

The great development in the use and application of machinery led rapidly to a demand for repetition work, both as regards the duplication of standard forms of machines and also for the production of spare parts and replacements for such machines. A demand for the rapid production of interchangeable parts could only be met by the introduction of methods whereby error was reduced to the extreme limit of possibility and machine work in engineering workshops became in consequence a matter of great precision in measurement. To-day, the general

standard of accuracy has reached a very high level of excellence, and in modern workshops the degree of precision expected as a matter of routine is as high as that which was formerly attained by an exceptionally skilled man engaged on the highest grade of work.

The degree of precision now obtainable in the work of the mechanic of average efficiency is largely the outcome of progress in the development of workshop gauges and measuring appliances, both as regards the construction of the machine tool by means of which he carries out his work, and in his gauging and checking of the work turned out by the machine. Apart from the various types of purely automatic machines, such as are found in all modern engineering shops engaged on repetition work, the machine tool of the present day is controlled as regards extent and variation of work, by the mechanic in charge of it. The precision of the work is dependent on the accuracy of the measuring tools and appliances at his command and on his skill in using them. The enormous importance of a thorough understanding of such appliances and the correct methods of using them will therefore be readily understood, and it is believed that this small volume will afford a useful introduction to the subject.

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AND

ΞASURING APPLIANCES

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CHAPTER I

STANDARD UNITS OF MEASUREMENT

ear Measurements.

ε simplest form of measurement consists in ing some standard length as a unit, and ex-
ssing the linear distance between two points erms of this unit, its multiples or subdivisions. linear units recognized in this country are the tish standard—the yard, and the Continental ıdard—the metre.

Standard Yard.

'he length of the standard yard is purely arbi-
'y, and is defined by Act of Parliament* as ows—

ıe straight line or distances between the centres of the sverse lines in the two gold plugs in the bronze bar deposited he office of the Exchequer† shall be the genuine standard l at 62° F., and if lost it shall be replaced by means of its es

---

18 and 19 Vict, c 72, July 30th, 1855.

In accordance with the Weights and Measures Act of 1878, British standards of measurement are now deposited at the ıdards Office of the Board of Trade; copies of the standard l are kept at the Houses of Parliament, the Mint, the Royal ety of London, the National Physical Laboratory and at the al Observatory, Greenwich

The bronze bar in question is one inch square in cross section and thirty-eight inches long. A small gold stud is inserted at a distance of one inch from each end of the bar, and it is on the faces of these two studs that the transverse lines giving the standard unit of one yard are engraved. The standard is exact only when measurement is made at a temperature of 62° F., the distance between the lines being greater at higher (and less at lower) temperatures.

Divisions of the Yard.

The yard as a unit of measurement is obviously too long for the measurement of small work, and consequently it is divided into three equal parts, termed feet; a foot is again subdivided into twelve equal parts termed inches. Where British units are employed, practically all workshop dimensions are expressed in terms of feet and inches.

Fractions and Decimal Subdivision.

Parts of an inch may be indicated either as fractions or as decimals. In the fractional system, the figure below the cross line, or at the right of the diagonal line, is termed the "denominator," and indicates the number of parts into which the inch has been divided; while the figure above the cross line, or to the left of the diagonal line, is the "numerator," and indicates the number of these parts in the dimension to be expressed. Usually the binary system of fractions is employed, in which each subdivision is one-half the value of the preceding division, i.e. $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$; this system has

ome the accepted method of subdivision of the h for the majority of work, though in some tances, e.g. in connection with gear wheel dimen-as, odd fractions, such as $\frac{1}{6}$, $\frac{1}{7}$, $\frac{1}{12}$, are employed h advantage. In very fine work, such as where ler gauges are used (see p. 67), it is usual to ress measurements in thousandths of an inch. n the decimal system of subdivision, the method building up a whole number in multiples of ten employed also in dealing with fractions less than ty. The first figure after the decimal point has unity value of one-tenth of one; the second re after the decimal point has a unity value of -hundredth of one , the third, one-thousandth one; the fourth one ten-thousandth of one; l so forth. Each succeeding figure indicates a mber of divisions, each of which has one-tenth unity value of the preceding division. Thus, 416 inch signifies three inches *plus* one-tenth *s* four hundredths *plus* one-thousandth *plus*

TABLE I

DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH

$\frac{1}{32}$	·03125	$\frac{3}{8}$	·37500	$\frac{23}{32}$	·71875
$\frac{1}{16}$	·06250	$\frac{13}{32}$	·40625	$\frac{3}{4}$	·75000
$\frac{3}{32}$	·09375	$\frac{7}{16}$	·43750	$\frac{25}{32}$	·78125
$\frac{1}{8}$	·12500	$\frac{15}{32}$	·46875	$\frac{13}{16}$	·81250
$\frac{5}{32}$	·15625	$\frac{1}{2}$	·50000	$\frac{27}{32}$	·84375
$\frac{3}{16}$	·18750	$\frac{17}{32}$	·53125	$\frac{7}{8}$	·87500
$\frac{7}{32}$	·21875	$\frac{9}{16}$	·56250	$\frac{29}{32}$	·90625
$\frac{1}{4}$	·25000	$\frac{19}{32}$	·59375	$\frac{15}{16}$	·93750
$\frac{9}{32}$	·28125	$\frac{5}{8}$	·62500	$\frac{31}{32}$	·96875
$\frac{5}{16}$	·31250	$\frac{21}{32}$	·65625	1	1·00000
$\frac{11}{32}$	34375	$\frac{11}{16}$	·68750		

six ten-thousandths of an inch, i e. three complete inches and $\dfrac{\text{one thousand four hundred and sixteen}}{\text{ten thousandths of an inch}}$

The decimal equivalents of various fractions of an inch are given in Table I.

The Metre.

The use of the metre* as a unit of length throughout Great Britain was legalized by Act of Parliament in 1907. Unlike the standard yard in its origin, the metre was intended to be a precise relation of the earth's dimensions, and it was stated to be one ten-millionth of the distance between the North Pole and the Equator, measured over the surface of the earth along the meridian passing through Paris. The original measurement of the arc of this meridian was carried out by Delambre and Mechain between Barcelona and Dunkirk, and the original standard metre was constructed by Borda. Actually, however, there were certain errors in the original calculation of the metre, and it is now defined as the distance between the two ends of the platinum rod originally constructed by Borda, the measurement being carried out at a temperature of 0° Centigrade (32° Fahrenheit).†

The relation between the metre and the yard is—

1 metre = 1·093633 yard = 39·37079 inches
1 yard = 0 9143935 metre

---

* The metre became the French standard unit of length in accordance with the law of the French Republic in 1795.

† *Cf* the temperature of 62° F. at which the British standard yard is to be measured, and see pp. 1 and 2 In America several firms are standardising the metre at 68° F and 62° F, but in England the metre is legally standard at 0° C

TABLE II

Quivalents of Inches and Fractions of an Inch Millimetres

0″	1″	2″	3″	4″	5″
——	25·399	50 799	76·199	101 59	126 99
0 794	26·193	51·593	76 992	102 39	127·79
1·587	26·987	52·387	77·786	103 18	128·58
2 381	27·781	53·180	78 580	103·97	129 37
3 175	28·574	53·974	79 374	104·77	130 17
3·969	29·368	54·768	80·167	105 56	130 96
4 762	30·162	55 561	80 961	106 36	131 76
5 556	30 956	56 355	81·755	107 15	132·55
6 350	31·749	57 149	82·549	107 94	133 34
7 144	32 543	57 943	83·342	108 74	134 14
7 937	33 337	58 736	84·136	109 53	134 93
8 731	34·131	59 530	84 930	110 32	135 72
9 525	34 924	60 324	85·723	111 12	136 52
10 319	35 718	61 118	86·517	111·91	137·31
11 112	36 512	61 911	87·311	112·71	138·11
11 906	37 306	62 705	88·105	113·50	138·90
12 700	38·099	63 499	88·898	114 29	139 69
13 494	38·893	64 293	89·692	115 09	140 49
14 287	39·687	65 086	90·486	115 88	141·28
15 081	40·481	65 880	91·280	116 67	142 07
15 875	41·274	66 674	92·073	117 47	142 87
16 668	42 068	67 468	92·867	118 26	143 66
17·462	42 862	68 261	93·661	119 06	144·46
18·256	43·655	69 055	94·455	119 85	145·25
19 050	44·449	69 849	95 248	120 64	146 04
19·843	45 243	70 642	96 042	121 44	146 84
20·637	46 037	71 436	96 836	122·23	147 63
21 431	46 830	72 230	97 629	123·02	148 42
22·225	47·624	73 024	98 423	123·82	149 22
23·018	48 418	73 817	99 217	124 61	150·01
23 812	49·212	74 611	100 011	125 41	150·81
24 606	50·005	75 405	100 804	126 20	151 60

TABLE II (continued)

Equivalents of Inches and Fractions of an Inch in Millimetres

6″	7″	8″	9″	10″	11″	Inches
152·39	177·79	203·19	228 59	253·99	279·39	0
153 19	178·59	203 99	229 39	254 78	280·18	1/32
153 98	179 38	204·78	230 18	255 58	280 98	1/16
154 77	180·17	205 57	230 97	256·37	281·77	3/32
155 57	180·97	206·37	231·77	257 17	282·57	1/8
156·36	181·76	207·16	232 56	257 96	283 36	5/32
157·16	182·55	207·95	233·35	258·75	284·15	3/16
157·95	183 35	208·75	234·15	259·55	284 95	7/32
158·74	184 14	209·54	234 94	260 34	285 74	1/4
159·54	184·94	210·34	235·73	261·13	286 53	9/32
160·33	185·73	211·13	236 53	261·93	287 33	5/16
161·12	186·52	211·92	237 32	262·72	288 12	11/32
161·92	187 32	212·72	238 12	263·52	288·92	3/8
162 71	188·11	213 51	238 91	264 31	289·71	13/32
163·51	188 90	214 30	239·70	265 10	290 50	7/16
164·30	189 70	215·10	240·50	265·90	291 30	15/32
165·09	190 49	215·89	241·29	266 69	292·09	1/2
165·89	191·29	216 69	242·08	267·48	292·88	17/32
166·68	192·08	217·48	242·88	268·28	293 68	9/16
167 47	192 87	218 27	243 67	269 07	294·47	19/32
168 27	193·67	219·07	244·47	269·87	295·27	5/8
169·06	194·46	219 86	245 26	270·66	296·06	21/32
169·85	195·25	220·65	246 05	271 45	296·85	11/16
170 65	196·05	221 45	246·85	272 25	297·65	23/32
171·44	196·84	222 24	247·64	273·04	298 44	3/4
172 24	197·64	223·04	248·43	273 83	299 23	25/32
173·03	198·43	223 83	249 23	274 63	300·03	13/16
173 82	199·22	224·62	250·02	275 42	300·82	27/32
174 62	200·02	225·42	250 82	276 22	301 62	7/8
175·41	200·81	226 21	251·61	277·01	302·41	29/32
176 20	201·60	227·00	252·40	277 80	303·20	15/16
177·00	202 40	227 80	253·20	278 60	304·00	31/32

TABLE III

Equivalents of Millimetres in Inches

Ins	Mm.	Ins.	Mm.	Ins	Mm.	Ins	Mm.	Ins.
·039	51	2 008	101	3 976	151	5 945	201	7 913
·079	52	2 047	102	4·016	152	5 984	202	7·953
118	53	2·087	103	4 055	153	6 024	203	7·992
·157	54	2·126	104	4·095	154	6 063	204	8 032
197	55	2 165	105	4·134	155	6 102	205	8 071
236	56	2 205	106	4 173	156	6 142	206	8·110
276	57	2 244	107	4·213	157	6 181	207	8·150
315	58	2 283	108	4·252	158	6·221	208	8·189
·354	59	2 323	109	4 291	159	6 260	209	8·228
394	60	2 362	110	4·331	160	6 299	210	8·268
·433	61	2 402	111	4·370	161	6 339	211	8·307
·472	62	2 441	112	4 409	162	6 378	212	8 347
·512	63	2 480	113	4 449	163	6 417	213	8 386
·551	64	2 520	114	4 488	164	6 457	214	8 425
·591	65	2 559	115	4 528	165	6 496	215	8 465
·630	66	2 598	116	4 567	166	6 535	216	8·504
·669	67	2 638	117	4 606	167	6 575	217	8 543
·709	68	2 677	118	4 646	168	6 614	218	8·583
748	69	2 717	119	4 685	169	6·654	219	8 622
787	70	2 756	120	4 724	170	6·693	220	8 661
827	71	2 795	121	4 764	171	6 732	221	8 701
866	72	2·835	122	4 803	172	6 772	222	8·740
906	73	2 874	123	4 843	173	6 811	223	8·780
945	74	2 913	124	4 882	174	6 850	224	8·819
984	75	2 953	125	4 921	175	6 890	225	8 858
1·024	76	2·992	126	4 961	176	6 929	226	8·898
1 063	77	3·032	127	5 000	177	6 969	227	8·937
1 102	78	3 071	128	5 039	178	7 008	228	8·976
1 142	79	3·110	129	5 079	179	7 047	229	9·016
1 181	80	3 150	130	5 118	180	7 087	230	9 055
220	81	3·189	131	5·158	181	7 126	231	9 095
260	82	3 228	132	5 197	182	7 165	232	0 134
299	83	3·268	133	5 236	183	7 205	233	9·173
339	84	3 307	134	5 276	184	7 244	234	9·213
·378	85	3 346	135	5 315	185	7·284	235	9·252
·417	86	3 386	136	5 354	186	7 323	236	9·291
·457	87	3 425	137	5·394	187	7 362	237	9·331
496	88	3 465	138	5 433	188	7 402	238	9·370
·535	89	3 504	139	5 472	189	7 441	239	9 410
·575	90	3 543	140	5 512	190	7 480	240	9 449
614	91	3 583	141	5 551	191	7 520	241	9·488
·654	92	3 622	142	5 591	192	7 559	242	9·528
·693	93	3 661	143	5 630	193	7 598	243	9·567
732	94	3 701	144	5 669	194	7 638	244	9·606
772	95	3 740	145	5 709	195	7 677	245	9 646
·811	96	3 780	146	5 748	196	7·717	246	9 685
·850	97	3 819	147	5 787	197	7 756	247	9 724
890	98	3·858	148	5 827	198	7·795	248	9 764
·929	99	3 898	149	5·866	199	7 835	249	9 803
969	100	3 937	150	5·906	200	7 874	250	9·843

·83)

TABLE III (continued)

Equivalents of Millimetres in Inches

Mm.	Ins.	Mm.	Ins	Mm.	Ins	Mm	Ins.	Mm.	Ins.
251	9 882	301	11 850	351	13 819	401	15·788	451	17·756
252	9·921	302	11 890	352	13 858	402	15·827	452	17·795
253	9 961	303	11 929	353	13·898	403	15 866	453	17 835
254	10 000	304	11 969	354	13·937	404	15 906	454	17·874
255	10 039	305	12 008	355	13 977	405	15 945	455	17 914
256	10 079	306	12 047	356	14 016	406	15 984	456	17 953
257	10·118	307	12 087	357	14 055	407	16·024	457	17 992
258	10 158	308	12 126	358	14·095	408	16·063	458	18 032
259	10·197	309	12 165	359	14 134	409	16·103	459	18 071
260	10 236	310	12 205	360	14 173	410	16·142	460	18·110
261	10 276	311	12 244	361	14 213	411	16 181	461	18 150
262	10 315	312	12 284	362	14 252	412	16 221	462	18·189
263	10·354	313	12 323	363	14 291	413	16 260	463	18·229
264	10 394	314	12·362	364	14 331	414	16 299	464	18·268
265	10 433	315	12 402	365	14 370	415	16 339	465	18·307
266	10·473	316	12 441	366	14·410	416	16 378	466	18·347
267	10 512	317	12 480	367	14 449	417	16 417	467	18·386
268	10 551	318	12 520	368	14 488	418	16 457	468	18·425
269	10 591	319	12·559	369	14 528	419	16·496	469	18·465
270	10·630	320	12·599	370	14·567	420	16 536	470	18 504
271	10 669	321	12 638	371	14 606	421	16 575	471	18 543
272	10·709	322	12 677	372	14 646	422	16 614	472	18 583
273	10·748	323	12 717	373	14·685	423	16 654	473	18 622
274	10·787	324	12·756	374	14·725	424	16 693	474	18 662
275	10 827	325	12·795	375	14 764	425	16 732	475	18 701
276	10 866	326	12·835	376	14 803	426	16 772	476	18 740
277	10·906	327	12 874	377	14·843	427	16 811	477	18 780
278	10 945	328	12·913	378	14·882	428	16 851	478	18 819
279	10·984	329	12 953	379	14 921	429	16·890	479	18 858
280	11 024	330	12 992	380	14 961	430	16 929	480	18·898
281	11·063	331	13·032	381	15 000	431	16 969	481	18·937
282	11·102	332	13 071	382	15 040	432	17 008	482	18 977
283	11·142	333	13·110	383	15 079	433	17 047	483	19 016
284	11·181	334	13·150	384	15 118	434	17 087	484	19·055
285	11 221	335	13 189	385	15 158	435	17 126	485	19 095
286	11 260	336	13·228	386	15 197	436	17·166	486	19 134
287	11·299	337	13·268	387	15 236	437	17·205	487	19·173
288	11·339	338	13 307	388	15·276	438	17 244	488	19 213
289	11 378	339	13 347	389	15 315	439	17 284	489	19 252
290	11·417	340	13 386	390	15 354	440	17 323	490	19·292
291	11 457	341	13 425	391	15·394	441	17·362	491	19 331
292	11·496	342	13·465	392	15 433	422	17·402	492	19 370
293	11 536	343	13 504	393	15 473	443	17·441	493	19·410
294	11 575	344	13 543	394	15 512	444	17 480	494	19·449
295	11 614	345	13·583	395	15·551	445	17 520	495	19·488
296	11 654	346	13 622	396	15 591	446	17 559	496	19·528
297	11·693	347	13 662	397	15 630	447	17 599	497	19·567
298	11·732	348	13·701	398	15·669	448	17 638	498	19·606
299	11·772	349	13 740	399	15 709	449	17 677	499	19·646
300	11 811	350	13 780	400	15 748	450	17·717	500	19·685

TABLE III (continued)

EQUIVALENTS OF MILLIMETRES IN INCHES

Ins	Mm.	Ins.	Mm	Ins	Mm	Ins.	Mm.	Ins.
19 725	551	21 693	601	23 662	651	25 630	701	27·599
19 764	552	21·732	602	23 701	652	25 670	702	27·638
19 803	553	21 772	603	23 740	653	25 709	703	27 677
19 843	554	21 811	604	23 780	654	25 748	704	27 717
19 882	555	21·851	605	23·819	655	25 788	705	27·756
19 921	556	21 890	606	23 858	656	25 827	706	27·796
19 961	557	21 929	607	23 898	657	25·866	707	27·835
20 000	558	21 969	608	23 937	658	25·906	708	27·874
20 040	559	22 008	609	23 977	659	25 945	709	27 914
20 079	560	22 047	610	24 016	660	25 984	710	27 953
20 118	561	22·087	611	24 055	661	26 024	711	27·992
20·158	562	22 126	612	24 095	662	26 063	712	28 032
20 197	563	22 166	613	24·134	663	26 103	713	28 071
20 236	564	22 205	614	24·173	664	26 142	714	28 110
20 276	565	22 244	615	24·213	665	26·181	715	28·150
20·315	566	22 284	616	24 252	666	26 221	716	28·189
20·355	567	22 323	617	24 292	667	26 260	717	28 229
20 394	568	22·362	618	24 331	668	26 299	718	28 268
20 433	569	22·402	619	24 370	669	26 339	719	28·307
20 473	570	22 441	620	24 410	670	26 378	720	28·347
20·512	571	22 481	621	24·449	671	26 418	721	28·386
20·551	572	22 520	622	24 488	672	26 457	722	28·425
20·591	573	22 559	623	24 528	673	26 496	723	28·465
20·630	574	22 599	624	24 567	674	26 536	724	28·504
20·669	575	22 638	625	24 607	675	26 575	725	28·544
20·709	576	22 677	626	24 646	676	26 614	726	28 583
20·748	577	22 717	627	24 685	677	26 654	727	28 622
20 788	578	22 756	628	24 725	678	26 693	728	28·662
20 827	579	22 795	629	24 764	679	26 733	729	28·701
20 866	580	22 835	630	24 803	680	26 772	730	28·740
20 906	581	22 874	631	24 843	681	26 811	731	28·780
20 945	582	22·914	632	24·882	682	26 851	732	28 819
20 984	583	22 953	633	24 921	683	26 890	733	28 859
21 024	584	22 992	634	24 961	684	26 929	734	28 898
21 063	585	23 032	635	25·000	685	26 969	735	28·937
21 103	586	23 071	636	25 040	686	27·008	736	28 977
21 142	587	23 110	637	25 079	687	27 047	737	29 016
21 181	588	23 150	638	25 118	688	27 087	738	29·055
21 221	589	23 189	639	25 158	689	27 126	739	29 095
21 260	590	23·229	640	25 197	690	27 166	740	29·134
21 299	591	23·268	641	25·236	691	27 205	741	29 173
21 339	592	23 307	642	25 276	692	27·244	742	29·213
21·378	593	23·347	643	25·315	693	27·284	743	29·252
21·418	594	23·386	644	25·355	694	27 323	744	29 292
21 457	595	23 425	645	25·394	695	27·362	745	29·331
21 496	596	23 464	646	25 433	696	27 402	746	29 370
21·536	597	23·503	647	25 473	697	27·441	747	29 410
21 575	598	23·543	648	25 512	698	27·481	748	29 449
21·614	599	23 582	649	25 551	699	27 520	749	29·488
21·654	600	23 622	650	25·591	700	27 559	750	29·528

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TABLE III (continued)

Equivalents of Millimetres in Inches

Mm	Ins.	Mm.	Ins	Mm	Ins	Mm.	Ins	Mm.	Ins
751	29 567	801	31 536	851	33 504	901	35 473	951	37·441
752	29 607	802	31·575	852	33 544	902	35 512	952	37 481
753	29·646	803	31 614	853	33 583	903	35·552	953	37·520
754	29 685	804	31·654	854	33 622	904	35 591	954	37 559
755	29 725	805	31 693	855	33 662	905	35 630	955	37 599
756	29 764	806	31 733	856	33 701	906	35 670	956	37 638
757	29 803	807	31·772	857	33 740	907	35 709	957	37 677
758	29 843	808	31·811	858	33 780	908	35 748	958	37 717
759	29 882	809	31·851	859	33 819	909	35 788	959	37 756
760	29 922	810	31·890	860	33·859	910	35 827	960	37 796
761	29 961	811	31 929	861	33·898	911	35 866	961	37·835
762	30 000	812	31 969	862	33 937	912	35 906	962	37 874
763	30·040	813	32 008	863	33 977	913	35 945	963	37 914
764	30 079	814	32 048	864	34 016	914	35 985	964	37 953
765	30 118	815	32 087	865	34 055	915	36 024	965	37 992
766	30 158	816	32·126	866	34 095	916	36 063	966	38·032
767	30 197	817	32 166	867	34 134	917	36 103	967	38 071
768	30 236	818	32 205	868	34 174	918	36 142	968	38 111
769	30 276	819	32 244	869	34 213	919	36·181	969	38 150
770	30 315	820	32 284	870	34 252	920	36·221	970	38 189
771	30 355	821	32 323	871	34 292	921	36 260	971	38 229
772	30 394	822	32 362	872	34 331	922	36·300	972	38 268
773	30 433	823	32·402	873	34 370	923	36 339	973	38 307
774	30 473	824	32 441	874	34 410	924	36 378	974	38 347
775	30 512	825	32 481	875	34 449	925	36 418	975	38 386
776	30·551	826	32 520	876	34·488	926	36 457	976	38 426
777	30 591	827	32 559	877	34 528	927	36 496	977	38·465
778	30 630	828	32·599	878	34 567	928	36 536	978	38 504
779	30 670	829	32·638	879	34 607	929	36·575	979	38 544
780	30 709	830	32 677	880	34 646	930	36 615	980	38 583
781	30·748	831	32 717	881	34 685	931	36·654	981	38·622
782	30 788	832	32·756	882	34 725	932	36 693	982	38 662
783	30 827	833	32·796	883	34·764	933	36 733	983	38·701
784	30·866	834	32 835	884	34 803	934	36 772	984	38 741
785	30 906	835	32 874	885	34 843	935	36 811	985	38 780
786	30 945	836	32·914	886	34 882	936	36 851	986	38 819
787	30 985	837	32 953	887	34·922	937	36 890	987	38·859
788	31·024	838	32 992	888	34 961	938	36 929	988	38·898
789	31·063	839	33 032	889	35 000	939	36 969	989	38·937
790	31 103	840	33·071	890	35 040	940	37 008	990	38 977
791	31·142	841	33 111	891	35 079	941	37·048	991	39·016
792	31·181	842	33 150	892	35 118	942	37 087	992	39 055
793	31·221	843	33 189	893	35 158	943	37 126	993	39·095
794	31·260	844	33 229	894	35 197	944	37·166	994	39·134
795	31·299	845	33·268	895	35 237	945	37·205	995	39·174
796	31·339	846	33 307	896	35 276	946	37·244	996	39·213
797	31 378	847	33 347	897	35 315	947	37 284	997	39·252
798	31 418	848	33 386	898	35 355	948	37·323	998	39 292
799	31 457	849	33 425	899	35 394	949	37 363	999	39 331
800	31 496	850	33 465	900	35 433	950	37 402	1000	39·370

ıe metre is divided into 10 decimeters (a term ɔm used in measurement); the decimeter is ded into 10 centimetres, and the centimetre 10 millımetres. Measurements smaller than mıllimetre are referred to as fractions or decimals millimetre.

ɔnversıons of British into Continental measurets, inches to millimetres and vice versa, are n in Tables II and III.

ɜurement by Comparison.

ıe fundamental prıncıple of all linear measuret consists in comparing, either directly or ·ectly, the distance between two or more points ɔne object with the distance between two or ɜ points on some other object. Measurement, ,s general sense, does not necessarily involve ɪse of numerical values or of graduated scales mon examples of measurement by direct parıson are seen when two pieces similar in ɔr shape are placed together or are superimposed one on the other for checking purposes, or ı a piece of cylindrical form or circular section sted ın the hole of another piece into which it tended to fit. Limit gauges (see p. 72) provide ıer examples of direct comparison of dimensions are largely used in modern workshop practice. ımiliar examples of indırect comparison are when a pair of calıpers (see p. 46) ıs first sted to fit over one piece of work or over a ɜrn, and is then tried over another piece in ess of manufacture; when an adjustable depth

gauge (see p. 77), is first set to the length of a plug and is then tested in the hole into which the plug is to fit; and when a template which has been made as a pattern is superimposed on the piece in process of manufacture as a check either on the work in progress or on the final completion of the work. In all methods of checking such as the above, measurement is made entirely by comparison and numerical values are not necessarily brought into use.

Generation of Length Standards by Comparison.

The importance of possessing accurate standards of length will be evident from what has already been said, and will be increasingly apparent from the later pages of this book. Without such standards, quantitative measurements would be an impossibility

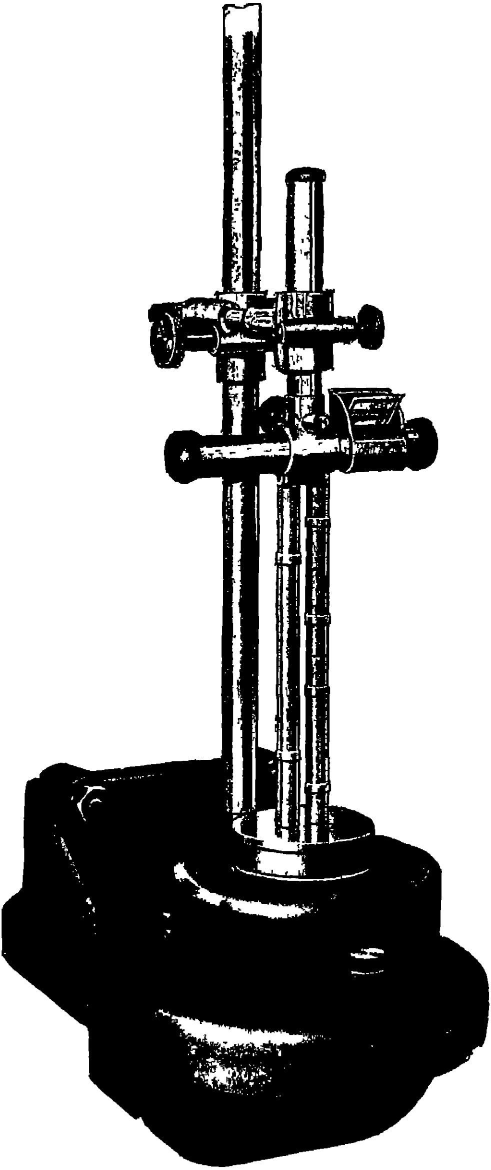
Subdivisions of standard lengths may be made by aid of a suitably calibrated measuring machine but, for the highest precision, it is best to adopt the system of "direct generation," which it is proposed to describe briefly, because it affords an excellent example of measurement by comparison, and a striking justification for Whitworth's prediction, made more than seventy years ago, that further advances in fine measuring depended principally upon truly flat surfaces.

The practicability of "generation of size" to a degree of accuracy suitable for the purpose considered depends upon making a new type of standard bar with the ends truly flat, parallel, and square

ı the axis to an order of accuracy approaching -millionth of an inch. Surfaces of the requisite ree of flatness are prepared by lapping on a › lapping plate (pp. 79, 102; see also Patent No. 149–1922), and the necessary high-precision ıparative measurements are made by means of generator comparator."

'he general appearance of the generator compara- in use is shown by Fig. 1. A massive casting 'ies a levelling base on which there is a platen ıble of being rotated so as to interchange two ȝ with regard to the contact balls of a high- ɔision level. The machine is entirely self- brating and self-adjusting without reference to exterior or previous calibration; also, it is a ıst piece of apparatus which can be used by average mechanic without special skill or pre- ıs experience. By means of the cross slides ve the level the whole of the upper surfaces of gauges resting upon the rotating platen can be lored.

parent bar is derived from the Legal Standard d and this can then be subdivided as required by process of direct generation. The actual manu- ıure of a full set of subdivisional standards ırally occupies a considerable length of time the principle employed is very simple and may compared with that used in the generation of ace plates (p. 102). The end bars or gauges ıg compared are placed side by side in a vertical ıtion on the rotating platen, and their relative ;hts are compared directly by means of the



Pitter Gauge & Precision Tool Co , Ltd

FIG 1 —GENERATOR COMPARATOR

Simultaneous comparison of two 6 in. bars against a 12-in bar

ion spirit level which spans across the ends of ırs. A little consideration will show that if any ›very two of three bars are together exactly to a 12-inch bar then each of the shorter nust be exactly 6 in. long. By working to a te programme of manufacture, the shorter ' generated " from a longer one can be made ;aneously and progressively to approach the subdivision required, and the principle thus r outlined can be applied to the generation of ›ver subdivisions may be desired.*

interesting point of great practical import- is that all bars so made from the same ›nt " standard, using the " generator com- ›r," will be true to size at the temperature ıich the parent bar is correct, although the l manufacture is carried out at ordinary work- temperature This assumes, of course, that ırs are all of the same material.

› two bosses or parts of larger diameter visible :h of the gauge bars in Fig 1 are called " nodal ." Their function is to support the bar at points that the ends of the bar remain truly el, whether the supporting surface be flat or horizontal or inclined. These bands are d, symmetrically with regard to the centre ɜ bar, at calculated positions which enable to fulfil their intended purpose.

ɪr a detailed explanation of the procedure adopted in ating " a full series of standards, the reader may be re- to a brochure entitled *Accuracy in Industry*, issued by ter Gauge and Precision Tool Co , Ltd , Woolwich, S.E.18, ing the processes invented at the National Physical tory by J. E Sears and A J C Brookes

The large measuring area on bars of this type (viz. that corresponding to $\frac{7}{8}$-in diameter) conduces to accuracy and prolongs the service life of the bars, whilst extending their applicability to workshop use, especially in combination with standard block and slip gauges (p. 79).

Eleven standard reference bars, of the following sizes in inches: 36, 30, 24, 18, 12, 6, 5, 4, 3, 2, and 1, can be used singly, or in "wrung together" combinations of two bars, to give all sizes from 1 to 42 inches, advancing by single inches. If used in conjunction with a set of 36 slip gauges these bars provide over 400,000 sizes advancing by single ten-thousandths of an inch!

It is claimed that the Pitter standard reference bars represent the world's highest accuracy in length measure up to 36 inches and, where necessary, they are guaranteed true to length within one part in a million in terms of the Imperial Standard Yard.

The uses of measuring bars and slip gauges for various workshop purposes are described later.

Angular Measurement.

Angular measurement provides a means of expressing numerically the inclination to one another of any two lines or planes. The dimensions of an angle can be determined from the magnitude of two linear distances at right angles to one another, and this method is frequently used in stating the dimensions of an inclination or of a taper, e.g.

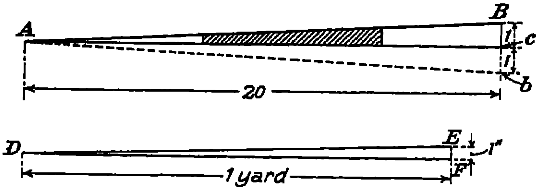


Fig. 2—Taper or Inclination Expressed as a Ratio of Linear Distances.

The inclination of the line *AB* with regard to *AC*, or the taper of the shaded key, is 1 in 20
(*Note.*—The line *BC* is at right angles to *CA* The length *AB* is $\sqrt{(20^2 + 1^2)} = 20{\cdot}025$ approximately).
The total taper of the two lines *AB*, *Ab*, is 2 in 20 or 1 in 10.
The inclination of *DE* with regard to *DF* is 1 in. in 1 yd (or 1 in 36)

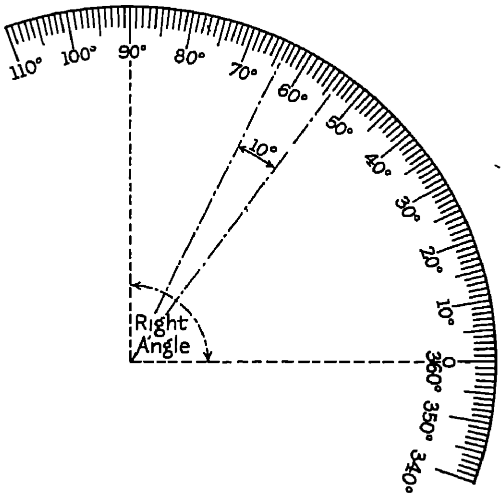


Fig. 3.—Part of a Circle Divided into Degrees.

1 in 20, or 1 inch in 1 yard (see Fig. 2). It is, however, more general, to express the angle between any two lines in terms of degrees or decimals of a degree.

In angular measurement by degrees the complete circle is divided into 360 equal parts, termed degrees (see Fig. 3). Two lines drawn from the centre of the circle to any two adjacent divisions are inclined to one another at one degree: 90 degrees, or the fourth part of one complete rotation of a line about a point is termed a "right angle."

Each degree is divided into sixty minutes, and a minute is divided into sixty seconds. The established symbols indicating degrees, minutes, and seconds are respectively °, ′, ″; thus, 46° 32′ 45″.

The division of a degree into minutes and seconds is used where great accuracy is required, but in ordinary workshop practice, it is generally more convenient to express an angular measurement of less than a degree as either a fraction or a decimal of a degree. Equal accuracy of expression is possible by this means—for example $46{\cdot}5458\dot{3}$ is exactly the same angle as 46° 32′ 45″—but the latter is the more convenient form, where this degree of precision is required.

Table IV shows angular and other equivalents of various tapers, and Table V, giving the decimal equivalents of the minutes and seconds of an angle, will be found useful.

Units of Mass.

Determination of the weight of a finished part

TABLE IV

Tapers and Angles

er 'oot	Complete Angle Included		Angle with Centre Line		Taper Per Inch	Taper Per Inch from Centre Line
	Deg.	Min	Deg.	Min.		
	0	36	0	18	010416	·005203
	0	54	0	27	015625	·007812
	1	12	0	36	·020833	·010416
	1	30	0	45	·026042	·013021
	1	47	0	53	·031250	·015625
	2	05	1	02	·036458	·018229
	2	23	1	11	·041667	·020833
	2	42	1	21	·046875	·023438
	3	00	1	30	·052084	·026042
	3	18	1	39	·057292	·028646
	3	25	1	47	·062500	·031250
	3	52	1	56	·067708	·033854
	4	12	2	06	·072917	·036456
	4	28	2	14	·078125	·039063
	4	45	2	23	·083330	·041667
	5	58	2	59	·104666	052084
	7	08	3	34	·125000	·062500
	8	20	4	10	·145833	072917
	9	32	4	46	166666	·083332
	11	54	5	57	208333	·104166
	14	16	7	08	·250000	125000
	16	36	8	18	·291666	·145833
	18	54	9	27	·333333	·166666
	21	14	10	37	·375000	·187500
	23	32	11	46	·416666	·208333
	28	06	14	03	·500000	·250000

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TABLE V

Minutes and Seconds of Arc expressed as Decimals of a Degree

MIN	0″	10″	20″	30″	40″	50″
0	·0	·00278	00556	·00833	·01111	·01389
1	·01667	·01944	·02222	025	·02778	03055
2	·03333	·03611	·03888	·04166	·04444	·04722
3	·05	·05278	·05555	·05833	06111	·06388
4	·06666	·06944	·07222	·075	07777	·08055
5	·08333	·08611	·08888	·09166	·09444	·09722
6	·1	·1028	·1055	·1083	·1111	·1139
7	·1167	·1194	·1222	·125	·1278	·1306
8	·1333	·1361	·1388	·1417	·1444	·1472
9	·15	·1528	·1556	·1583	·1611	·1639
10	·1667	·1694	·1722	·175	1778	·1805
11	·1833	·1861	·1889	·1917	·1944	·1972
12	·2	2028	·2056	·2083	·2111	·2139
13	·2167	·2194	·2222	·225	·2278	·2306
14	·2333	·2361	·2389	·2417	·2444	·2472
15	·25	·2527	·2555	·2583	·2611	·2639
16	·2667	·2694	·2722	·275	·2778	·2806
17	·2833	·2861	·2889	·2917	·2944	2972
18	·3	·3028	·3056	·3083	·3111	·3139
19	·3167	·3194	·3222	·325	·3278	·3306
20	·3333	·3361	·3389	·3417	·3444	·3472
21	·35	·3527	·3555	·3583	·3611	·3639
22	·3667	3694	·3822	·375	·3778	·3806
23	·3833	·3861	·3889	·3917	·3944	3972
24	·4	·4028	·4056	·4083	·4111	·4139
25	·4167	·4194	·4222	·425	·4278	·4306
26	·4333	·4361	·4389	·4417	·4444	·4472
27	·45	·4527	·4555	·4583	·4611	·4639
28	·4667	·4694	·4822	·475	·4778	·4806
29	·4833	·4861	·4889	·4917	·4944	·4972

TABLE V (continued)

0″	10″	20″	30″	40″	50″
·5	·5028	·5056	·5083	·5111	·5139
·5167	·5194	·5222	·525	·5278	·5306
·5333	·5361	·5389	·5417	·5444	5472
·55	·5527	·5555	·5583	·5611	5639
·5667	·5694	·5822	·575	·5778	·5806
·5833	·5861	·5889	·5917	·5944	·5972
·6	·6028	·6056	·6083	·6111	6139
·6167	·6194	·6222	·625	6278	6306
6333	·6361	·6389	·6417	·6444	6472
·65	6527	·6555	·6583	·6611	·6639
·6667	·6694	·6822	·675	·6778	·6806
·6833	·6861	·6889	·6917	·6944	·6972
·7	·7028	·7056	·7083	7111	·7139
·7167	·7194	·7222	·725	·7278	·7306
·7333	·7361	·7389	·7417	·7444	·7472
·75	·7527	·7555	·7583	7611	·7639
·7667	·7694	·7822	·775	7778	7806
7833	·7861	·7889	·7917	7944	·7972
·8	·8028	·8056	8083	·8111	·8139
·8167	·8194	·8222	·825	8278	·8306
·8333	·8361	·8389	·8417	·8444	·8472
·85	·8527	·8555	·8583	·8611	·8639
·8667	·8694	·8822	·875	·8778	·8806
·8833	8861	·8889	·8917	·8944	8972
·9	·9028	·9056	·9083	9111	·9139
·9167	·9194	·9222	·925	9278	·9306
·9333	·9361	·9389	·9417	9444	·9472
·95	·9527	·9555	·9583	9611	9639
·9667	·9694	·9822	·975	·9778	·9806
·9833	·9861	·9889	·9917	·9944	·9972

or piece of work is sometimes of considerable importance, e g. in flywheel calculations and in connection with governor control. It is necessary, therefore, to refer briefly to the methods of calculating the mass or weight of material.

The standard units of mass throughout Great Britain are the pound avoirdupois and the kilogram; in workshop practice the pound avoirdupois is used almost exclusively in this country. As in the case of the standard yard the weight of the standard pound is purely arbitrary, and is the mass of a piece of platinum preserved at the Standards Office of the Board of Trade.

The kilogram was intended to be a precise relation of an accessible commodity and was originally constructed by Borda to represent exactly the mass of a cubic decimetre of water at 4° Centigrade (the temperature at which water attains its maximum density). As in the case of the original measure of the metre, it is now known that Borda's measurement was not exact, and the kilogram is now defined as the mass of a piece of platinum preserved in Paris and termed the "kilogram des Archives."

A pound avoirdupois is equal to 0·45359265 kilogram, and a kilogram is equal to 2·20462125 pounds.

Values of British pounds in kilograms, and of kilograms in British pounds, are given in Tables VI and VII.

If the mass of any volume of a given substance be determined, and the mass of the same volume

TABLE VI

EQUIVALENTS OF POUNDS IN KILOGRAMS

Kilos	Lbs	Kilos.	Lbs.	Kilos	Lbs.	Kilos.
45359	26	11·79342	51	23 13324	76	34·47307
·90718	27	12·24701	52	23·58683	77	34·92666
1·36078	28	12·70060	53	24 04043	78	35 38025
1·81437	29	13·15420	54	24·49402	79	35·83384
2·26796	30	13·60779	55	24·94761	80	36·28744
2·72156	31	14 06138	56	25·40121	81	36·74103
3 17515	32	14 51497	57	25·85480	82	37 19462
3 62874	33	14 96857	58	26 30839	83	37 64822
4 08233	34	15 42216	59	26 76199	84	38·10181
4 53593	35	15 87575	60	27·21558	85	38·55540
4 98952	36	16 32934	61	27·66917	86	39 00900
5 44311	37	16 78294	62	28 12276	87	39 46260
5 89671	38	17·23653	63	28·57636	88	39 91618
6·35030	39	17 69012	64	29·02995	89	40·36977
6·80389	40	18 14372	65	29 48354	90	40·82337
7·25749	41	18·59731	66	29·93714	91	41·27696
7·71108	42	19 05090	67	30 39073	92	41·73055
8 16467	43	19 50459	68	30 84432	93	42 18415
8 61826	44	19 95810	69	31 29791	94	42 63774
9 07186	45	20 41168	70	31 75151	95	43·09133
9 52545	46	20 86527	71	32·20510	96	43·54493
9 97904	47	21·31887	72	32·65870	97	43 99852
0·43263	48	21·77246	73	33·11229	98	44·45211
)·88623	49	22·22605	74	33 56588	99	44 90570
1·33982	50	22·67965	75	34 01947	100	45·35930

TABLE VII

Equivalents of Kilograms in Pounds

Kilos.	Lbs.	Kilos	Lbs.	Kilos.	Lbs.	Kilos	Lbs.
1	2·205	26	57 320	51	112·435	76	167 550
2	4 409	27	59 524	52	114 639	77	169 754
3	6 614	28	61·729	53	116 844	78	171 959
4	8·818	29	63 933	54	119 048	79	174 163
5	11·023	30	66 138	55	121·253	80	176 369
6	13 228	31	68 343	56	123 458	81	178 573
7	15 432	32	70 547	57	125·662	82	180 777
8	17 637	33	72 752	58	127 867	83	182 982
9	19 842	34	74 956	59	130·071	84	185 186
10	22 046	35	77 161	60	132 277	85	187 391
11	24 251	36	79·366	61	134 481	86	189 596
12	26 455	37	81 570	62	136·685	87	191 800
13	28 660	38	83 775	63	138·890	88	194 005
14	30 864	39	85·979	64	141 094	89	196·209
15	33 069	40	88·184	65	143 299	90	198 416
16	35 274	41	90·389	66	145·504	91	200 619
17	37·478	42	92 593	67	147·708	92	202 823
18	39·683	43	94 798	68	149 913	93	205 028
19	41 887	44	97·002	69	152 117	94	207 232
20	44 092	45	99 207	70	154·323	95	209 437
21	46 297	46	101·412	71	156 527	96	211 642
22	48 501	47	103 616	72	158 731	97	213 846
23	50 706	48	105 821	73	160 936	98	216 051
24	52 910	49	108 025	74	163·140	99	218 255
25	55 115	50	110·231	75	165 345	100	220 462

ater, the first divided by the second gives the ocific gravity" of the substance, or—

$$\text{pecific gravity} = \frac{\text{Mass of any volume of substance}}{\text{Mass of equal volume of water}}$$

$$= \frac{\text{Weight of any volume of substance}}{\text{Weight of equal volume of water}}$$

ater has been adopted as a standard unit of since it is readily obtainable in a pure state, mogeneous, and has an invariable density at en temperature.

e specific gravities of some of the more common ances met with in engineering are shown in VIII.

lation of Weights.

e weight of 1 cu. ft. of water is, approximately, bs, so that, knowing the specific gravity of a ial, we can calculate the weight of any piece therefrom, by aid of the formula—

$$\text{t in lbs} = \text{Volume, in cu ft} \times \text{Specific gravity} \times 62{\cdot}3$$
$$= \text{Volume, in cub ins} \times \text{Specific gravity} \times 0\ 0361$$

most practical purposes, it is more convenient rk with the "density" of the material which ned as the mass of unit volume of the material s of density in lbs. per cu. in., and in lbs. per . are also given in Table VIII, and the weight y piece may be calculated from—

$$\text{in lbs.} = \text{Volume, in cu ft.} \times \text{Density, in lbs. per cu. ft.}$$
$$= \text{Volume, in cu ins.} \times \text{Density, in lbs per cu. in.}$$

TABLE VIII

SPECIFIC GRAVITIES AND DENSITIES OF COMMON SUBSTANCES
(*Approximate*)

Material	Specific Gravity	Density	
		Lbs. per cu. in.	Lbs. per cu. ft.
Water (fresh)	1·0	0·036	62 3
Oil—light	0·7–0·8	0 025–0·029	44–50
—heavy	0·88–0 96	0·032–0·035	55–60
Wood—soft	0 48–0·88	0·017—0·032	30–55
—hard	0·56–1·3	0·02–0·048	35–82
Brickwork	1·6–2 1	0 058–0·075	100–130
Concrete	2·2	0·081	140
Aluminium and its alloys	2·5–3 0	0 09–0 11	155–185
Iron and steel	7·2–7·9	0 26–0·28	450–490
Copper, brass and bronze	8·0–8 8	0 29–0·32	500–550
Lead	11 4	0·41	710
Mercury	13·6	0 49	850

CHAPTER II

SIMPLE MEASUREMENT

RE describing in detail the various instruments for measurement and gauging in ordinary shop practice, a brief statement of the method lculating the results of some of the simpler of such measurement may be given.

termination of a linear extent on a plane ce in terms of a standard unit is a direct ss: that is, the reading of the scale or the nce apart of the points of the calipers or other ment used gives the desired answer without calculation being necessary.

asurement of superficial area or of volumetric city, however, involves the taking of at least limensions, and the area or the volume is some ct of these dimensions.

t of Surface.

e superficial area of certain geometrical figures tained by simple calculation, and a few typical of such figures are given in Table IX. The r π (= ratio of the circumference to the eter of a circle) $= 3{\cdot}1416 = 22/7$ approximately.

urement of Volumetric Capacity.

me typical cases of geometrical figures are in Table X, the factor π being, as before, 6 or 22/7 approx.

TABLE IX

FORMULAE FOR SURFACE AREAS

Figure	Data	Surface
Square	a = length of side	a^2
Rectangle	a and b = length of two adjacent sides	ab
Parallelogram	a = height b = base	ab
Triangle	a = height b = base	$\frac{1}{2}ab$
Circle	r = radius d = diameter	πr^2 $\pi d^2/4$ $(= 0.7854d^2)$
Sphere	r = radius	$4\pi r^2$ $(= 12.566r^2)$
Cylinder	r = radius h = height	Curved surface = $2\pi rh$ Total, including ends = $2\pi r(r + h)$
Cone	r = radius of base h = height l = length of side (apex to base) = $\sqrt{r^2 + h^2}$	Curved surface (i.e. surface excluding base) = πrl

TABLE X

FORMULAE FOR THE VOLUME OF SOLIDS

Figure	Data	Volume
Cube	a = length of side	a^3
Rectangular parallel-sided body	a, b, c = lengths of three adjacent edges	abc
Sphere	r = radius d = diameter	$\frac{4}{3}\pi r^3$ $0.5236d^3$
Cylinder or Prism	r = radius of base h = height a = area of base	ah or $\pi r^2 h$
Cone	a = area of base r = radius of base h = height	$\frac{1}{3}ah$ or $\frac{1}{3}\pi r^2 h$

Parallax.

In simple measurement it is of the first importance that instruments suitable in every way be used for the precise measurement involved. As an example of this, the measurement of the diameter of a sphere may be instanced ; in this case the edges or points of the measuring appliance must be brought into

ıte contact with the dimensions to be measured, this is not effected, an appreciable error due parallax" may occur. Parallax may be d as the apparent change of position of an relatively to other objects when the aspect en from a different point or points. Errors parallax have to be guarded against in all of simple measurement, and also in the use truments for such purposes as land surveying, omical observations and the like. In the of the measurement of the precise diameter phere, the dimension cannot be even approxiy measured, without possibilities of grave by placing a rule over the object and attemptgauge the dimension by the eye. Some such ment as a pair of calipers or similar instrument ntial in obtaining a measurement of this kind. all cases where accurate observation is necesthe eye with which the measurement is to be must be perpendicularly in front of the point observed. In order to ensure perfect definition her eye of the observer should be closed. In a simple scale, the eye should first be placed ly vertical to the scale at the point where the bservation is to be made. The rule must then ljusted so that its end, or, alternatively, a e graduation on the rule, is exactly coincident the first point at which the observation is made. Great care must then be taken to that the rule is not moved in relation to the being measured until the completion of the l observation. The eye must then be brought

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perpendicularly in front of the second point to be observed, and the calibration mark on the scale which coincides with this second point on the part to be measured must then be read off. When the zero calibration on the scale has been set to the first point to be observed, the reading on the scale of the second point observed is, of course, the linear dimension required, where some other calibration mark has been taken for the first point observed, the required measurement is the reading at the second point observed less the reading at the first point of observation.

Linear Dimensions.

The instruments in general use in engineering workshops for the determination of linear dimensions are rules, calipers of various sorts, micrometers, height gauges, depth gauges, thickness gauges, rod gauges, and caliper or map gauges. Of these the simple rule is of the greatest general service

The Rule.

All rules as used in engineering workshops consist of flat straight strips of steel or other suitable material engraved on one or more edges with graduation marks which represent definite and stated proportions of the standard units of linear measurement. Rules are now available in a considerable variety of material, shape and graduation, and there is no difficulty in obtaining a rule to meet any possible requirement of work and to suit any conceivable individual taste. Rules for use by

ıanics are almost invariably made of steel; enters' and pattern makers' rules aro usually ard wood, e.g. box-wood; and tho scales or ı in use by draftsmen are usually of wood, ivory, ›, celluloid or cardboard.

rulo is generally rectangular ın cross section, ılternatively, has one or both edges bevelled For special purposes, rules having triangular, re, or elliptical cross section are sometimes loyed. The width of rules may be anything $\frac{1}{4}$ in. to 2 in., the thickness from $\frac{1}{64}$th to $\frac{1}{4}$ in. the length from 1 in. up to 6 ft. or more: rules › 12 in. in length are usually made in one piece, 'eas rules longer than this are generally made f hınged sections, so that they can be folded up eniently when not in use

uation of Rules.

ıe graduation of rules is carried out in a great ›ty of ways. In some cases, scales aro engraved oth sides of the rule and along both edges, so four different scales are provided on the same ; ın other cases, one side of the rule only is ıved, sometimes one scale being provided and ›times different scales being engraved along of the two edges.

ith the British standard system of measurement are generally divided usıng the binary system actions, and in some cases the decimal system ed. Rules having combinations of these two ›ms of dıvısıon are frequently employed. With Continental system of measurement, rules aro

generally divided into centimetres, millimetres, and half millimetres. It is usually the practice to engrave the finer divisions along a portion only of the scale, a rule divided in this way being generally easier to read correctly than where the fine divisions are engraved along the whole length of the scale. A typical example of a twelve-inch rule of this type is shown in Fig. 4 · in this case, one edge of the rule is divided into centimetres and millimetres throughout, the first 5 centimetres being divided into half millimetres; the second edge is divided into inches and sixteenths throughout, the first 3 inches are divided into 32nds, and half the fourth inch is divided into 64ths.

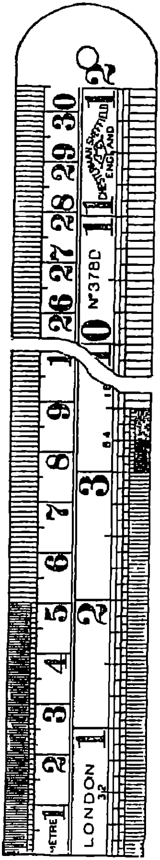

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FIG 4.—TYPICAL GRADUATION OF A 12-IN STEEL RULE

These rules are, of course, obtainable with a great variety of graduations.

By taking the completed inches in a dimension on the open portion of a scale and the fractional part of the dimension on the finely divided portion, any dimension within the capacity of the scale can be readily determined. Where the required dimension does not exactly coincide with a graduation

a the scale, the correct position that it ccupy on the scale between two adjacent s can be estimated, with a little practice, degree of accuracy

imon method of calibrating a rule carrying erent scales on the two sides and along the ;es is to divide the first scale into eighths, second into eighths and sixteenths, with the l last inches divided into sixteenths and condths respectively; the third scale into und twentieths, with the first and last inches hs and hundredths; and the fourth scale elfths and twenty-fourths. On many rules scale is provided, arranged down the centre ule (i.e. between two of the scales), or else he place of one of the inch scales along one in Fig. 4)

tting Rules.

inations of the binary fractional system he decimal system are frequently used. A on employed on gear-cutting work has four raduated as follows—

. 10ths, 20ths, 50ths and 100ths
. . . 12ths, 24ths and 48ths
. 16ths, 32nds and 64ths
. 14ths and 28ths

becial purposes some rules carry an additional scales graduated across one or both ends. a rule of this type is illustrated in Fig. 5, es shown being inches and eighths along one id inches, eighths and sixteenths along the edge; the scales engraved along the two

edges of the rule show thirty-seconds of an inch, the graduation being carried out from the bottom edge only of the scale and extending to a total of 14/32nds of an inch across each end of the scale.

Metric Rules.

Steel rules for workshop use are generally procurable in all lengths, ranging from five centimetres up to a metre. They usually carry two scales only, and are graduated into millimetres along one edge, and into millimetres and half millimetres along the

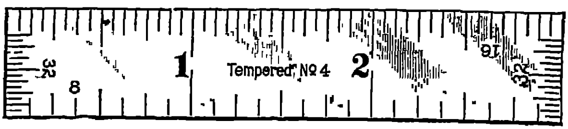

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FIG. 5—A 3-IN RULE WITH SCALES GRADUATED ACROSS THE ENDS

second edge Scales are sometimes engraved along one or both ends.

Metric and British Standard Rules.

In certain classes of work it is sometimes a great convenience to be able to read direct at will in either British or Continental standard measurement, and, for this purpose, special rules with metric and British standard scales are available. The graduation is generally in millimetres and half millimetres along one edge, and in inches, sixteenths and thirty-seconds along the other edge. Rules of this type are generally obtainable in lengths of from 5 centimetres (1·9685 inches) up to a metre (39·37 inches).

nkage or Contraction Rules.

or all ordinary measurement one or other of numerous patterns of standard rules is used. attern maker, however, when making a pattern ı which a casting is to be produced, uses a ial rule in which the true distances apart of the luations are greater than those represented on scale, since allowance has to be made for the ıkage of the casting after the metal has been ·ed into the mould made in the sand. The perature of the molten metal ıs, of course, very , and as the casting cools it shrinks, and the ern used must, therefore, be slightly larger than finished casting is required to be. The amount ırınkage varies with the material being cast, and, ›me cases, with the nature of the casting.*

ıe usual allowances made with various materials ›ach foot in length are as follows—

TABLE XI

ɪKAGE ALLOWANCES FOR CASTINGS IN VARIOUS METALS

Metal	Shrinkage Allowance ın Inches per foot length		
and Iron .	1/10	or	0·1000
ıetal . .	1/8	,,	0·1250
ı . . .	3/16	,,	0·1875
. .	5/16	,,	0·3125
.	5/16	,,	0·3125
. . . .	1/4	,,	0·2500
ər . .	3/16	,,	0·1875
uth . . .	5/32	,,	0·1563
able Iron .	1/8	,,	0·1250
ınıum . .	1/5	,,	0·2000

*ee also *Patternmaking* and *Foundrywork*, by Ben Shaw ames Edgar, Pıtman's Technical Primer Serıes, 2s. 6d each

The use of shrinkage rules enables a pattern to be made to the dimensions given on a drawing for a finished casting and yet to be just the right amount larger in every direction to allow for the difference in size between the mould and the resultant casting. They save the pattern maker the time required otherwise for numerous calculations and allowances, and eliminate the risk of error in such calculations

Shrinkage rules are generally procurable in English measurement in lengths of 6, 12, and 24 inches, with shrink allowances per foot varying from $\frac{1}{12}$in. up to $\frac{7}{16}$in. In metric standard they are obtainable up to a length of 30 centimetres, with shrink allowances equivalent to those given above.

Precautions with Shrink Rules.

To avoid any possible misuse or mistake, shrinkage rules should always be distinctly marked in the clearest possible manner to the effect that they are shrink rules, and as to the amount of shrink allowed, thus—

SHRINK 1/8″ to foot
or
1: 96

They should always be kept under lock and key in the particular place (e.g pattern shop) where they are to be used, and on no account should they ever be allowed in a machine shop.

Steel Tapes.

For correct measurement of long lengths the steel measuring tape is a most useful appliance.

es of woven material cannot be depended upon vork where real accuracy is required, since they liable to stretch with use and to stretch or ık with varying atmospheric conditions. Steel suring tapes are obtainable in great variety, ıng in length from 3 feet up to 100 feet. The ter lengths of from 3 feet up to 36 feet are those commonly employed in engineering practice. ıe tape itself, of these measures, is usually of flexible steel strip, finished with a black ıce on which the figures and graduation marks arried in a bright finish, so that they are easily able against the black background. The steel is usually from $\frac{1}{4}$ to $\frac{5}{8}$ inch in width.

useful form of measure for the shorter lengths the steel tape wound on a spring-controlled contained in a flat circular metal case (Fig. 6). e the length of tape required is pulled out and ented from being drawn back into the case ı the tension is removed by a simple automatic ıet on the spring-controlled drum. When the urement has been completed the ratchet ıanism is released by a push button and the is automatically rewound.

eel tapes as usually obtained, are graduated r in feet, inches and eighths of an inch, or in es, centimetres and millimetres. Where the ic system is used, it is generally the practice aduate the first 10 centimetres in millimetres the remainder of the tape in centimetres and es. A variety of other graduations can be ob-d for special purposes, e.g. architects, builders,

surveyors, etc. Steel tapes with British standard measurement on one side and with metric measurement on the reverse are also obtainable (see Fig. 6).

The Vernier.

In the measurement of length by means of a scale, difficulty sometimes occurs in reading frac-

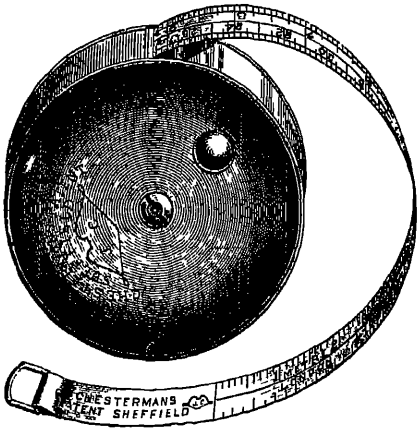

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FIG. 6—STEEL TAPE MOUNTED ON SPRING-CONTROLLED DRUM IN METAL CASE.

The tape illustrated has four scales, two on each side

tional parts of the smallest division on the scale or in reading off accurately the precise dimension indicated on the scale. It is, of course, quite possible to graduate a division of one inch into as many as one hundred equal parts, and to do this with a high degree of accuracy. With a scale of this type it is theoretically possible to read off

ngth accurately to $\frac{1}{100}$th of an inch, but the en-
ved lines showing each division are very close
ther and it is not always easy to distinguish
n or to obtain a result free from inaccuracies.
eady means of reading accurately with the
imum possibility of error is provided in what
nown as the vernier—a device owing its origin
ierre Vernier, who invented it in 1631.
ypical caliper gauges with verniers are illustrated
igs. 8 to 11, and the method of reading the
ier may be explained by reference to Fig 7.
ith very few exceptions, n divisions on the
ier are made equal to $(n - 1)$ divisions on the
scale. Then if s be the length of one main
division, and v be the length of one vernier
sion, we have. $n \times v = (n - 1) \times s$, or $v =$
1) s/n Now the smallest possible reading on
vernier equals the difference between one
ion on the main scale and one division on the
ier, i.e. $s - v$. This reading is called the "least
t" of the vernier, and, substituting the above
e for v, we have—

$$\text{Least count} = s - v$$
$$= s - \frac{(n-1)\,s}{n}$$
$$= \frac{s}{n}$$

Fig. 7, 25 divisions on the vernier = 24 divi-
on the main scale. The main scale (which is
n larger than full size, for clearness) measures
s and fortieths of an inch; hence $s = \frac{1}{40}$ or
in., and $n = 25$. The "least count" is

therefore 0·025/25 = 0·001, or 1-1000th of an inch.

Reading first on the main scale up to the zero point on the vernier, we find that the measurement illustrated in Fig 7 is $1'' + \frac{3}{10}'' + \frac{1}{40}''$ + a fraction of $\frac{1}{40}''$, i.e. 1·325″ + a fraction which is read on the vernier. The fraction in question is $\frac{4}{1000}''$, for the *fourth* vernier line coincides with one of the main scale lines, and each vernier division equals 1/1000 in.

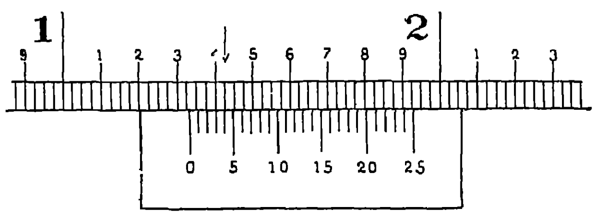


FIG. 7.—ILLUSTRATING METHOD OF READING THE VERNIER.

The measurement in the case illustrated is 1 329 in.

The complete reading is therefore 1·325 + 0·004, or 1·329 in.

The rule for reading this particular vernier may be summarized thus—

1. Read the numbers of inches, tenths, and *complete* fortieths on the main scale up to the zero of the vernier.

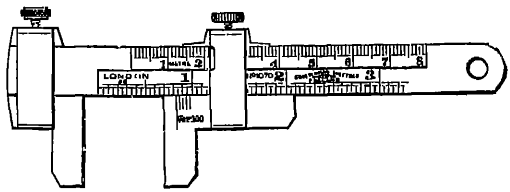
2. Note the number of the vernier line (counting from zero on the vernier scale) which coincides with a line on the main scale, then this is the number of thousandths to be added to the main scale reading.

3. When reading internal measurements the

h of the two jaws must be added to the actual ing unless another vernier is provided specially nternal measurements.

›llowing the procedure laid down above, the er will see that—

) In Fig. 8, the vernier reads to 100ths of an , and the measurement illustrated is 0·8 + 0·02 82 in



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IG. 8 —CALIPER GAUGE WITH VERNIER READING TO 100THS OF AN INCH.

This gauge has an adjustable head which, when worn, can be removed, tried, and re-set

In Fig. 9, the inch-vernier reads to 1000ths n Fig. 7) and the reading is $\frac{1}{40}'' + \frac{9}{1000}'' =$; + 0·009 = 0·034″.

In Fig. 9, the centimetre vernier has 25 divi- equal to 24 divisions on the main scale. Each e main scale divisions equals $\frac{1}{20}$ cm. or 0·05 cm., e the vernier reads 0·05/25 or 0·002 cm., i.e. m. as its " least count." The reading illustrated nm. + $\frac{18}{50}$ mm. = 0·5 + 0·36 = 0·86 mm.

As a check, the zeros of the inch and centi- e scales in Fig. 9 being coincident, and 1 in. ; 25·4 mm., the metric reading should be × the inch reading as obtained at (*b*), i.e.

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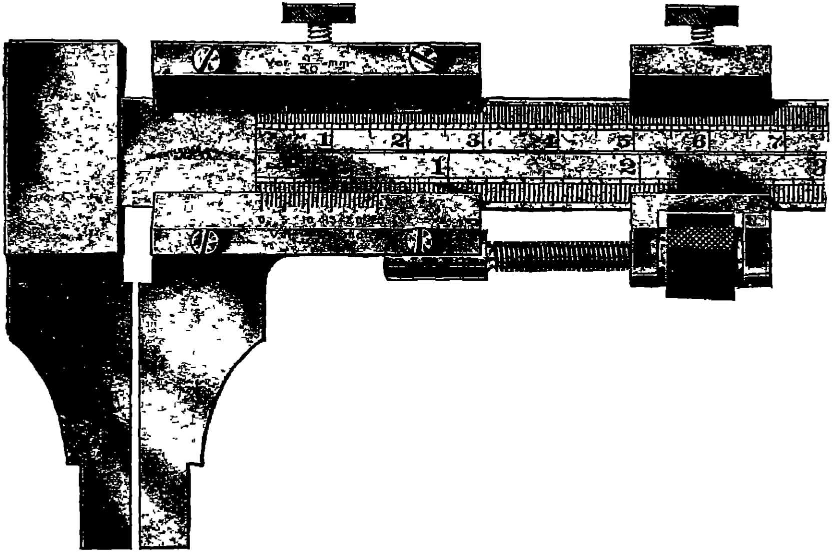

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FIG 9.—CALIPER GAUGE WITH VERNIERS READING TO 1000THS OF AN INCH AND 50THS OF A MM

This tool can be used as a caliper gauge (inside and outside) and is also graduated on the back for use as a depth gauge

: 0·034 or 0·864 mm., which agrees with the obtained at (*c*).

example of an angular vernier is shown in 9 (p 116), and the method of reading it is explained.

a full treatment of different types of verniers, r numerous examples in the reading of different ;s on all types of instruments and tools where rs are employed, the reader should refer to *ietic for Engineers* (2nd edition), by C. B. ım.*

ernier caliper reading to 0·001 inch (and not ric units) is shown in Fig. 10.

steel slide rule or gauge shown in Fig 11 is for check measurements on end measuring pin gauges, and the like. It is a highly d tool with screw adjustment and verniers g to thousandths of an inch or fiftieths of a etre. The measurement is taken from the ıed steel plugs (shown in Fig. 11) and both al and external readings may be taken. If red, flat jaws may be substituted for the plugs.

nation End-Measuring Bars.

s similar to the Standard Reference Bars əed on p. 13, are supplied for workshop use. uch service an accuracy of 5 parts in one ı is ample and is, indeed, higher than has to been placed in the workshop for lengths 40 inches This accuracy represents an error ; than one ten-thousandth of an inch in 20

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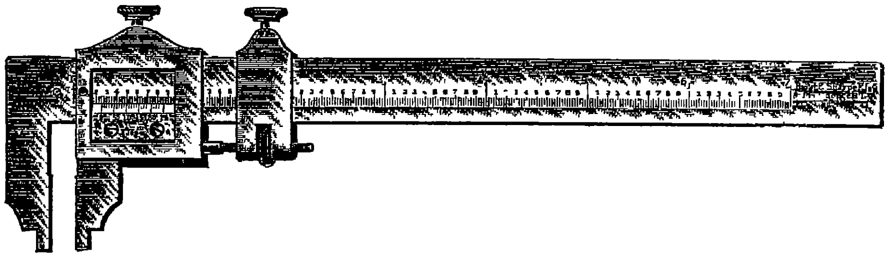

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FIG. 10.—VERNIER CALIPER GAUGE READING TO 1000THS OF AN INCH.

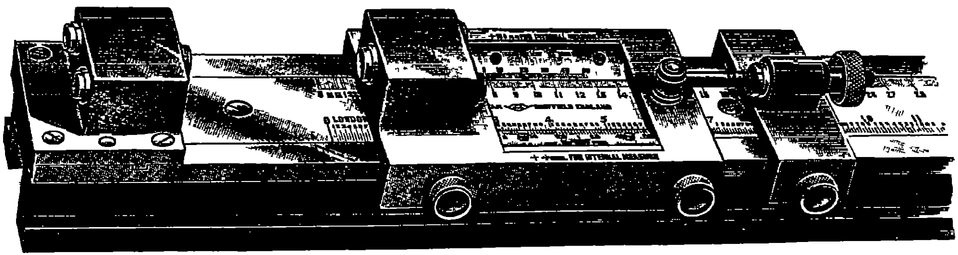

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FIG 11.—STEEL SLIDE RULE OR GAUGE WITH VERNIERS READING TO 0·001 INCH AND 0·02 MM

ɘs in terms of the Imperial Standard Yard. ıer accuracy can be obtained if required, at ɜr cost.

set of such bars of sizes, in inches, 32, 23, 15, 6, 5, 4, 3, 2, and two 1-inch bars, will give all from 2 to 39 ınches advancıng by single inches, ombinations of two bars only, which are conɘd by a simple screw joint. The joints are

Pitter Gauge & Precision Tool Co , Ltd

Fig. 12.—Workshop Combination End Bar and Accessories shown Dismantled

ided at one end only, so that the composite ıas always two flat and parallel end measuring- ı to which slip gauges (p. 79) can be added by ıs of simple extension collets. A typical comtion end bar and accessorıes is shown in Fig. nd it may be mentioned that the twelve bars ıerated above, together with a 36-piece set ip and block gauges, gives more than 380,000 sızes. They provide a means of applying size, ɔtly to work in operatıon, in a manner whıch ıs ɔssible by any other known means with the same ee of accuracy.

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CHAPTER III

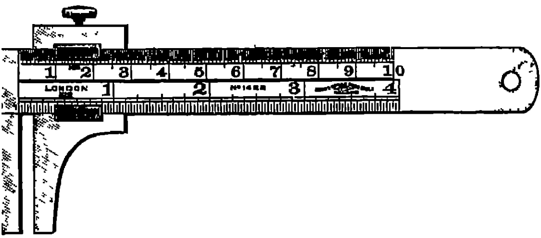
INDIRECT MEASUREMENT

In very many instances it is not possible to measure off or to check the dimension of a part by direct application of the rule. It then becomes necessary to use some instrument which will gauge accurately the dimensions of the part to be measured, and to check this measurement against a standard rule. In other cases where a comparison of dimensions is being made against a dimensioned drawing or a standard pattern to which the finished part is to conform, it is necessary to check from time to time the progress of the work. The measuring appliances most commonly used in this way are various kinds of calipers and standard limit gauges.

Calipers.

In many classes of work, sufficient accuracy is obtained by judging by the eye the position of the point to be measured in relation to the graduation of the instrument (e.g scale). It is, however, not always convenient or possible to place the edge of the rule in the required position, or to read the scale accurately when it is in such a position, for such purposes measuring instruments having two points of contact are necessary. In certain of these instruments scales are incorporated which show directly the precise dimension between the two points of contact, and in others the dimension is

obtained on the instrument and the distance of the points is then determined, either by arison with a standard scale or by checking st a pattern or the like. Instruments of the r class include the usual forms of slide calipers, t and depth gauges: in the latter class are led the various types of ordinary calipers oth inside and outside measurement.



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13.—SIMPLE CALIPER GAUGE, DIVIDED INTO 32NDS OF AN INCH AND HALF-MILLIMETRES

he screw for fastening the sliding jaw cannot become detached from the gauge

Calipers.

th these instruments one point of contact is ally fixed and the other is adjustable In use xed point is placed against one surface and the table point is brought up against the other e. The distance apart of the two points of ct is read directly on the scale incorporated e instrument.* Instruments of this type are ally procurable in lengths of from 6 to 12 inches rom 15 to 30 centimetres

any forms of slide calipers have a depth gauge incorporated hem and carry both a British and a metric scale.

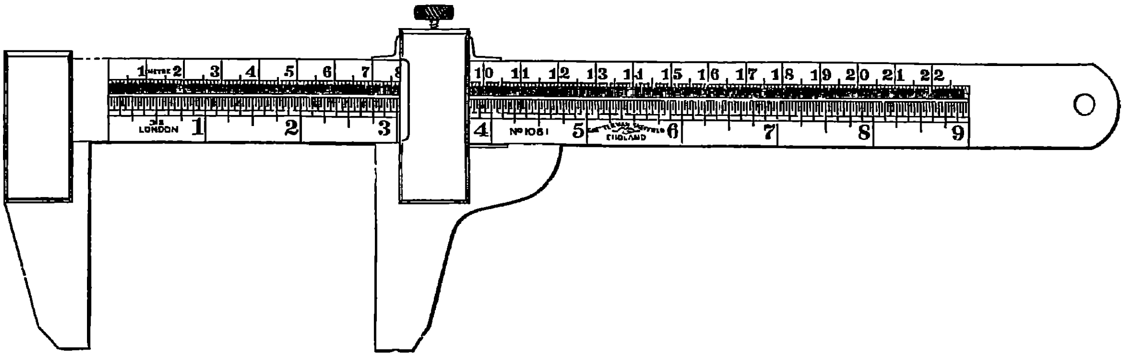

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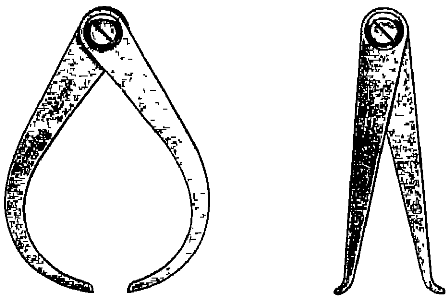
FIG. 14 —SIMPLE SLIDE CALIPER WITH BRITISH AND METRIC SCALES

A simple form of slide caliper gauge is shown in ;. 13, and a larger instrument of the same general)e is shown in Fig. 14. In the latter case the ıtish scale reads up to 9 inches by 32nds of our h, and the metric scale up to 23 centimetres ›prox.) by half-millimetres. The movable contact ı be locked in position, when the instrument is



Brown & Sharpe Mfg Co

FIG 15.—FIRM-JOINT CALIPERS FOR OUTSIDE (LEFT) AND INSIDE (RIGHT) MEASUREMENTS.

ıusted to the desired dimension, by means of the mp or locking screw seen at the top of the frame which the movable contact piece is carried.

A more elaborate form of slide caliper is shown Fig. 9 (p. 42). Inside and outside measuring ınts are provided; the sliding jaw can be locked any desired position by means of the clamp, and ›at nicety of adjustment of the contact points obtained by the micrometer screw adjustment. rniers are provided on both the British and the ›tric scales, the British scale reading to 1/1000th

inch and the metric scale to 1/50th millimetre. The method of reading the verniers is explained on p. 39.

Inside and Outside Calipers.

Typical examples of reliable forms of inside and outside calipers for ordinary work are shown in Fig. 15. The legs are of tempered steel, the stud at their junction being provided with a thread which screws into the washer. The washer is secured by means of flats engaging with a corresponding hole in the leg. This method of making the joint on which the legs move ensures a constant degree of friction the amount of which can be varied by the user to suit his individual requirements.

Calipers of this type are normally supplied with narrow points, but for special purposes broad points are obtainable. Narrow points are more useful for a greater range of work. Outside calipers of the ordinary form are procurable in sizes of from 3 inches up to 36 inches: inside calipers of this type are not usually made in sizes over 24 inches.

A second form of inside and outside calipers combined in one instrument is shown in Fig. 19. This type of instrument is particularly useful for small work, and is made in various sizes up to 8 inches.

In using calipers, as, for instance, in determining the diameter of a cylindrical piece of work with outside calipers, or the bore of a cylinder with inside calipers, considerable care is required, since instruments of this class are easily strained and rendered

less for very accurate work. Calipers should er be applied to gauge the diameter of a piece vork whilst it is revolving in a lathe or in any other chine tool; the legs of a caliper can be sprung rt by the exercise of only a moderate amount of e and measurements taken from moving parts frequently inaccurate and misleading.

nside and outside calipers should be opened by ling the legs apart until the points are separated. final adjustments must be made by gentle ping of the inside or the outside of the leg against ie hard surface until the distance apart of the its exactly coincides with the required dimension. ticular care must be taken that the tapping is taken on the contact points

n reading off the distance apart of the points a caliper, a good method, where practicable, is place one point on a truly accurate plane sur-e, e.g a surface plate. The scale is then placed tical to the surface and the measurement made the scale with the observer's eye at right angles the scale. Lack of care in checking the dimen-n of a caliper reading may easily result in siderable inaccuracy of work

ing Calipers.

For use where great accuracy is required spring pers are frequently employed. Typical exam-s of this type of instrument are shown in Fig

Instruments of this class can be set with great uracy and considerable rapidity to any desired iensions within their range. They are generally

obtainable in sizes of from 3 up to 6 inches radius of leg.

Inside calipers of this type are particularly useful as transfer calipers for use in any chambered cavity, since—after being set exactly to the desired dimension—they can be withdrawn by springing back the legs; on being released after withdrawal they return to their original setting and show exactly the size which has been calipered.

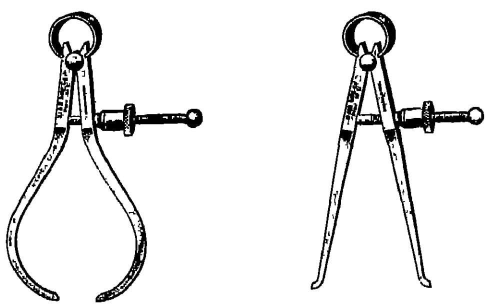


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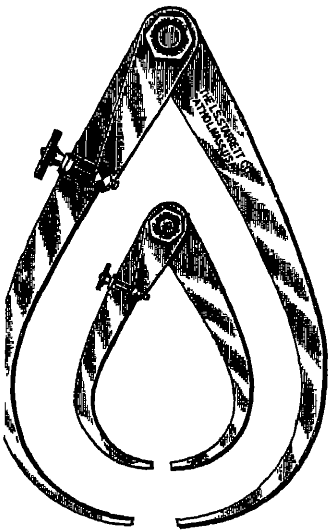
FIG 16.—OUTSIDE (LEFT) AND INSIDE (RIGHT) SPRING CALIPERS.

A special form of calipers of the spring type, known as tool makers' calipers, resemble those shown in Fig. 16 except that the legs are made from round bar drawn down and are especially tough and of rigid construction. The stud, screw thread, and all parts subject to wear are hardened. This type is usually procurable in sizes of from 2 to 6 inches radius of leg.

Many other forms of calipers are made and retailed

pecial purposes, the great number of which ıde specific mention. There are, however, special features of certain types of calipers ı may be mentioned briefly.



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ıG. 17.—OUTSIDE CALIPERS WITH SCREW ADJUSTMENT

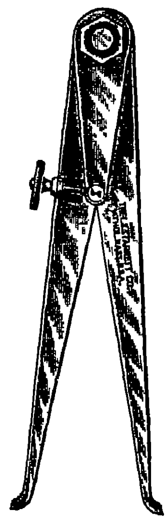

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FIG. 18 —INSIDE CALIPERS WITH SCREW ADJUSTMENT.

v Adjusting Calipers.

ır large scale work it is not generally possible tilize calipers of the spring type and in some ; the accuracy possible with the ordinary type lipers, such as are illustrated in Figs. 15 and 16, t sufficient. In such cases a very useful device

is provided in the screw-adjusting calipers shown in Figs. 17 and 18. With these instruments the correct setting is obtained approximately by the ordinary method and final adjustment is made by the fine

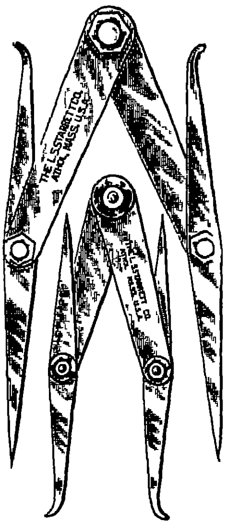

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FIG. 19.—COMBINED DIVIDERS, INSIDE AND OUTSIDE CALIPERS

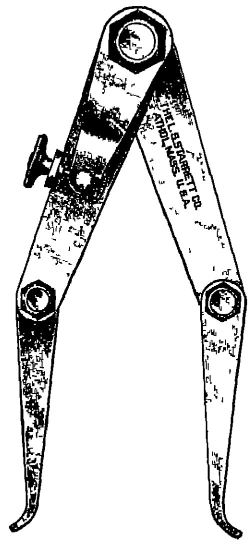

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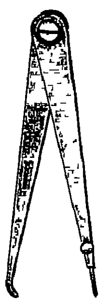
FIG. 20.—REVERSIBLE INSIDE AND OUTSIDE CALIPERS WITH SCREW ADJUSTMENT

adjustment screw on one leg. By this means the calipers can be adjusted with very great accuracy to any required setting, either for comparison purposes or for checking against any required dimension. They are obtainable in sizes of from 4 inches up to a maximum of 36 inches.

uble calipers, such as are illustrated in Figs. ıd 20, are useful tools, combining the advan- of dividers and of both ınside and outside ›rs They are usually sold in 6 and 8 inch only, and, for special purposes, have the fine adjustment shown in Fig. 20



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. 21 —FIRM-JOINT
ıPHRODITE CALIPERS

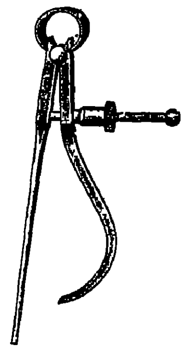

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FIG. 22 —KEYWAY
SPRING CALIPERS.

aphrodite Calipers.

ıse are largely used for findıng the centre of or for testıng the accuracy of a centre already ıd. In this form of calipers one leg is similar › leg of a compass calipers, and, in the best ›f the instrument, is provıded with a renewable ; the second leg is the same in principle as of an ordınary calipers. When used to ıe centre of a cylinder or of a hole, the bore cylinder or hole must bo plugged before tho phrodite calıpers are applied.

A typical instrument of this class is shown in Fig. 21, in which the needle point is adjustable by means of the thumb screw in the leg. This allows for wear on the point. Such calipers are usually obtainable in sizes of from 4 up to 10 inches radius of leg.

Keyway Calipers.

Another useful special type of calipers is the keyway or keyhole spring-type instrument shown in Fig. 22.

Special Types of Inside Calipers.

For inside measurements where the distance between two points is too great or too inconvenient for the extent to which ordinary inside calipers can be used, an instrument is sometimes employed which consists essentially of two legs held together by screws threaded into nuts. The screws are formed with shoulders fitting into the slots on the two legs which form guides on which the legs move. The nuts on the screws are set so as to bind the legs together, but to allow them to move slightly in relation to one another when either end of the legs, remote from the points, is struck by a light tapping. When the points are adjusted to their exact dimension required, the locking screws are firmly fixed home.

An instrument of this type is often accurate enough for ordinary work, but where extreme

,cy is required special types of inside calipers metimes employed. These generally consist l tubes telescoping the one into the other and ıg at one end either a one-inch or a 25-milli- micrometer screw movement. With this ɔf instrument measurement can be carried er a range of from 30 to over 100 inches or uivalent ın millimetres, with an accuracy of th inch, or 1/100th mıllımetre.

[or Screw Pitch Gauges.

principal thread systems used in Great ı are the Whitworth form of thread and the Association thread. These systems are lly abbreviated and are known as the B.S.W. e B.A. threads. Whitworth thread propor- re much used on the continent to millimetre ·ions ; other threads in use on the continent ıe De Lisle, the Systeme Internationale, he Thury. The United States standard is largely used throughout America and ι.

Whitworth form of thread is defined by the Engineering Standards Association* as —

/hıtworth form of thread ıs one in whıch the angle the flanks, measured ın the axial plane, is 55°; one- the sharp triangle is truncated at top and bottom, the ɔeıng rounded equally at crests and roots to a radius therefore 0·137329 times the pıtch; the depth of the 0·640327 times the pıtch.

ıcatıon C.L. (M) 7270, June, 1919.

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The British Association form of thread is defined by the British Engineering Standards Association* as follows—

> The British Association form of thread is one in which the angle between the flanks, measured in the axial plane, is 47·5°; the threads are rounded equally at crests and roots to a radius of nearly two-elevenths of the pitch, leaving the depths of threads given in Table I.†

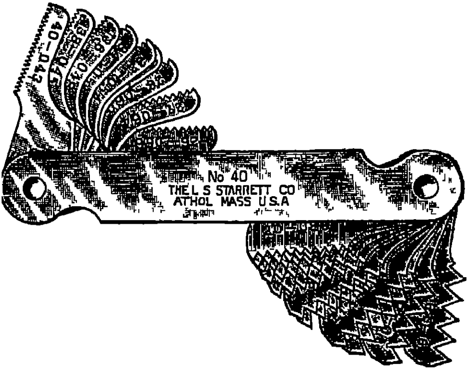
The United States standard thread (known also as the Sellers, or Franklin Institute Thread) has an angle between the flanks of 60° with flat crest and roots.

It is frequently necessary to determine the pitch of a screw or of a threaded piece of work; this can readily be determined by the use of screw pitch guages, typical examples of a gauge of this type being shown in Figs. 23 and 24. The instrument consists of a series of leaves carrying standard thread pitches; the standard of each leaf is clearly stamped or engraved on the face of the leaf and the leaves are hinged at one end to fold into a case when not in use. The thread system with which the gauge complies (e.g British Standard Whitworth, British Association) is engraved or stamped on the case

In use the thread system is first determined by examination; various leaves of the gauge are then placed successively over the thread until one leaf is found to coincide with the thread; the pitch is

* Publication C.L. (M) 7271, June 1919

† See page 12 of Publication C.L. (M) 7271, June, 1919.



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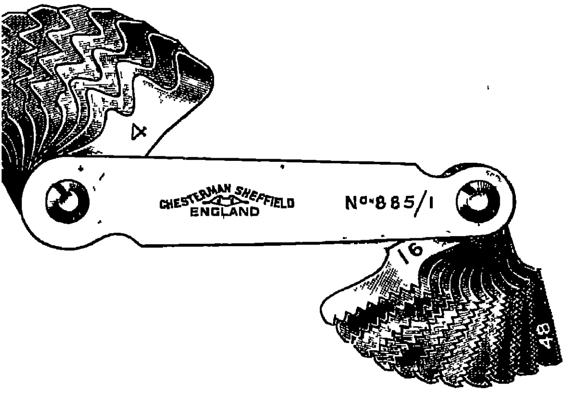
23 —Screw Pitch Gauge, Showing Threads per Inch and Double Depth of Thread



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'IG 24 —Whitworth Standard Screw Pitch Gauge

then read off from the number engraved or stamped on this particular leaf

Gauges of this type are generally obtainable in British and metric standards for all thread systems, and are made up with from 20 to 30 pitches of varying standards ranging from 4 down to 80 pitches per inch.

The free end of each leaf (Fig. 23) is made narrow to enter a small hole or nut, so that internal as well as external threads can be gauged. The first number on each blade is the number of threads per inch.

The second (decimal) number stamped on each leaf is the double depth of the thread to which that leaf corresponds. The use of this number is as follows: When a hole is to be tapped, measure the diameter of the tap over the threads by a micrometer and deduct the decimal number given on the gauge leaf which agrees with the pitch of the tap. The result gives the diameter of drill to be used if a full thread is to be cut. If the thread is to be not full but flattened, allowance must be made for the amount by which it is to be flattened.

The screw pitch is sufficiently accurate for ordinary workshop use, but special methods must be employed for the measurement or checking of screw gauges, lead screws, and other threads in which a very high degree of accuracy is required. For a full treatment of the theory and practice of precision measurements on screw threads, the reader may be referred to publications issued by the National Physical Laboratory (see Bibliography, p. 148).

Gauges.

ıere a number of measurements of the diameters ɜtal, wire, or rod have to be made, it ıs often ɜnient to use one or other of the numerous ɜ of notched steel gauges now universally nable. In this type of gauge, the widths of ıotches are equal to the recognized standards, are numbered so that by reference to a table liameter of any wire or rod corresponding to 'en gauge number can be readily ascertained. nples of two well-known forms of this type of e are given in Figs. 25 and 26. Generally, a of wire gauge numbers and the corresponding eters of wire is stamped on the back of the e plate.

should be noted that gauges of this type, i.e. ıg notches, are not suıtable for the accurate urement of sheet metal, since the edges of such s frequently vary from the thickness of the of the sheet.

hen gauges of this type are used they are red to slip over the thickness of the metal e measured and the consequent friction and ing tend to cause a minute enlargement of the ı; their accuracy is, therefore, gradually oyed. It is also a disadvantage that they will letermine thicknesses intermediate between any gauge numbers. The micrometer caliper (p. s not subject to this limitation and can be ɜted to compensate for wear.

e thickness corresponding to a given wire e number varies according to the system

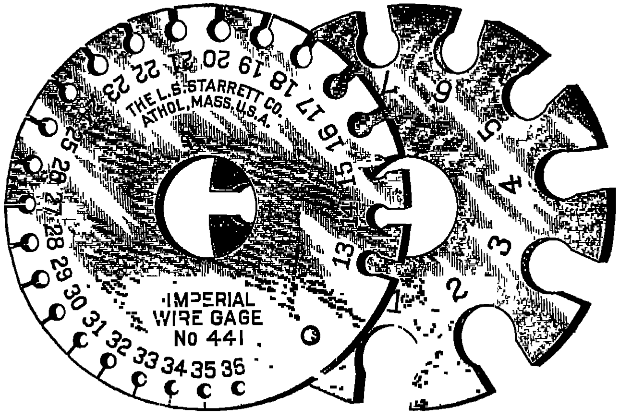

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FIG. 25—IMPERIAL STANDARD WIRE GAUGES.

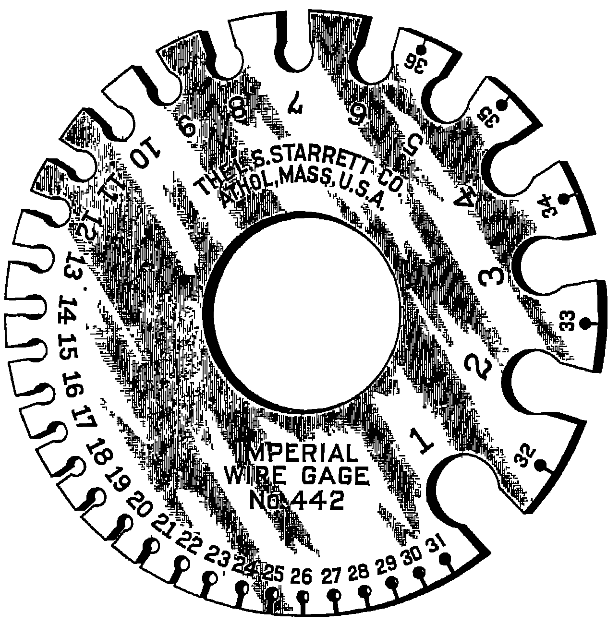

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FIG. 26.—IMPERIAL STANDARD WIRE GAUGES.

ning the numbering of the gauge, and also the class of metal or wire for which the gauge een constructed. For ordinary work throughout t Britain the Imperial Standard and the ingham (also known as the Stubbs) wire es are those most frequently employed; see es XII and XIII.

gauge system in common use throughout the ed States is the American Standard, which is known as the Brown and Sharpe Gauge (Table). In this system the value of 0·46 in. has been n as the thickness corresponding to the largest nsion of the gauge; each of the 43 successive between 0000 (or 4/0) and 40 gauge is decreased uniform decrement, namely by multiplying its cessor by 0·890522. The value for B. & S. e number 36 is 0·005 in., which corresponds with ber 35 on the Birmingham wire gauge.

e advantages of the United States system is the gauges are easier to produce than those ructed to a scale in which each figure does bear a proportionate value to the preceding ; the difference between any two gauge bers in the B. & S. series is easily found by lation.

rious other standards are in use for special oses; such as those for sheet iron (Table XV), music wire, for rolled sheets of silver and gold, heet zinc, and for numerous other purposes. workshop mechanic in this country is, how- mainly concerned with the Standard and the ingham wire gauges.

TABLE XII

IMPERIAL STANDARD WIRE GAUGE

Descriptive number	Equivalent in parts of an inch	Metric equivalent mm	Sectional area of wire	
			Square in	Square mm
7/0	·500	12 700	·1963	126·67
6/0	·464	11·785	·1691	109 09
5/0	·432	10 973	·1466	94·56
4/0	400	10 160	·1257	81·07
3/0	372	9·449	·1087	70 12
2/0	·348	8·839	·0951	61·36
0	324	8·229	0824	53 19
1	·300	7·620	0707	45 60
2	·276	7·010	·0598	38·58
3	252	6·401	·0499	32·18
4	·232	5·893	·0423	27 27
5	·212	5·385	0353	22 77
6	192	4 877	·0289	18 68
7	·176	4·470	·0243	15 70
8	·160	4·064	0201	12·97
9	·144	3·658	0163	10·51
10	·128	3·251	·0129	8 30
11	116	2·946	0106	6 82
12	.104	2 642	00849	5 48
13	·092	2·337	00665	4·29
14	080	2·032	·00503	3·24
15	·072	1 829	·00407	2·63
16	064	1 626	00322	2·07
17	056	1·422	·00246	1·59
18	·048	1·219	·00181	1·17
19	040	1 016	·00126	·811
20	·036	·914	·00102	·657
21	032	813	·00804	519
22	·028	711	000616	397
23	·024	·610	000452	292
24	022	·559	·000380	·245
25	·020	·508	·000314	·203
26	·018	·457	·000254	164
27	·0164	4166	·000211	·136
28	·0148	·3759	·000173	·111
29	·0136	·3454	000145	·0937
30	·0124	3150	000121	·0779
31	·0116	2946	·000106	0682

TABLE XII—(continued)

rip- e ber	Equivalent in parts of an inch	Metric equivalent mm	Sectional area of wire	
			Square in.	Square mm.
2	·0108	2743	·0000916	·0591
3	0100	·2540	·0000785	·0507
4	·0092	·2337	·0000665	0429
5	·0984	·2134	0000554	·0357
6	·0076	1930	·0000454	·0293
7	·0068	·1727	·0000363	·0234
8	·0069	·1524	·0000283	·0182
9	0052	·1321	·0000212	·0137
0	·0048	·1219	·0000181	·0187
1	·0044	1118	·0000152	·00982
2	·0040	1016	·0000126	·00811
3	·0036	·0914	0000102	·00656
4	0032	·0813	·00000804	·00519
5	0028	0711	·00000616	·00397
6	·0024	0610	·00000452	·00292
7	·0020	0508	·00000314	00203
8	·0016	·0406	·00000201	00129
9	·0012	0305	·00000113	·00073
0	·0010	·0254	·000000785	·00051

TABLE XIII

BIRMINGHAM (STUBBS) WIRE GAUGE

Size in inches	Descriptive number	Size in inches	Descriptive number	Size in inches	Descriptive number	Size in inches
·454	7	180	17	·058	27	·016
·425	8	·165	18	·049	28	·014
·380	9	·148	19	·042	29	·013
·340	10	·134	20	·035	30	012
·300	11	120	21	·032	31	·010
·284	12	109	22	·028	32	·009
·259	13	·095	23	·025	33	008
238	14	·083	24	·022	34	·007
220	15	072	25	·020	35	·005
·203	16	065	26	·018	36	·004

TABLE XIV

AMERICAN (BROWN & SHARPE) WIRE GAU

Descriptive number	Size in inches	Descriptive number	Size in inches	Descriptive number	Size in inches	Descriptive number
4/0	4600	8	·1285	19	0359	30
3/0	·4096	9	·1144	20	·0320	31
2/0	·3648	10	·1019	21	·0285	32
0	3249	11	0907	22	·0253	33
1	2893	12	0808	23	0226	34
2	2576	13	·0720	24	0201	35
3	2294	14	·0641	25	0179	36
4	·2043	15	0571	26	·0159	37
5	1819	16	·0508	27	·0142	38
6	·1620	17	·0453	28	·0126	39
7	·1443	18	·0403	29	0113	40

TABLE XV

BIRMINGHAM SHEET IRON GAUGE

Descriptive number	Size in Inches	Descriptive number	Size in Inches	Descriptive number
1	·3125	12	·1125	23
2	·28125	13	·10	24
3	·25	14	0875	25
4	·234375	15	·075	26
5	21875	16	0625	27
6	·203125	17	05625	28
7	1875	18	·05	29
8	171875	19	·04375	30
9	·15625	20	·0375	31
10	·140625	21	·034375	32
11	·125	22	·03125	

kness or Feeler Gauges.

ı many cases of assembly and fitting work, in numerous other instances, it is frequently ired to determine the dıstance apart of two ıl surfaces or the degree of approximation of surfaces to one another. It is not always possible scertain this dımension by direct measurement

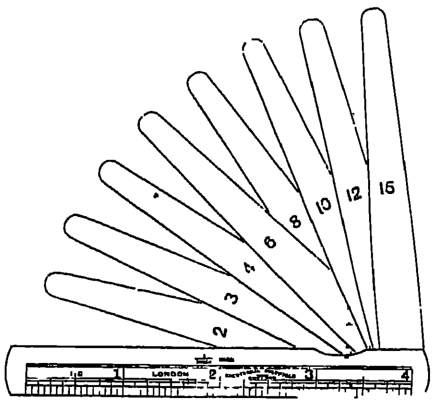

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FIG 27.—FEELER OR THICKNESS GAUGE.

y the use of insıde calipers, partıcularly where dimension concerned is very small, and ın work ,his class thickness or "feeler" gauges are uently employed

ǝeler gauges are usually made up in leaves ed together at one end and folding into a convent case. The leaves are usually from 3 to 4 in. by ½ in wide, being eıther parallel throughout r length or tapering towards their free ends. number of leaves in a set range normally from

6 to 10, and vary in thickness from 0·0015 up to 0·025 in. in British standard measurement and from 0·05 millimetre upwards in the metric system. A typical feeler gauge is shown in Fig. 27. The thickness in thousandths of an inch or in hundredths of a millimetre is engraved clearly on each leaf, leaves may be used singly or in combination with other leaves and any thickness within the limits of the various combinations permissible, can readily be determined by trial and error.

Plug and Ring (or Collar) Gauges.

Gauges of this type provide standards of diameter for general workshop use; as generally supplied for ordinary workshop use they provide a limit of accuracy within 1/500th part of an inch A typical set of such plugs and gauges is shown in Fig. 28, the diameter of the plugs and the bores of the rings generally advance by $\frac{1}{16}$ in. from $\frac{3}{16}$ to 2 ins., by $\frac{1}{8}$ in. from 2 to 4 ins, and by $\frac{1}{4}$ in. from 4 to 8 in, or by similar increments in metric measure. The gauges are of hardened steel, lapped to size, and they are applied to the work in course of manufacture or to the finished piece in order to ascertain whether the diameter of a hole (tested by the plug gauge), or of a turned spindle, etc. (tested by the ring gauge), is or is not equal to that of the gauge. There is no means of determining by these gauges the magnitude of any difference between the diameters of the gauges and of the work, but an experienced workman can estimate the difference approximately by the "feel" of the next smaller plug or next larger ring, as the

may be. There are available plug and ring
es of diameters corresponding to various
es of fit—e.g. force, driving, push, and running
on or in different nominal diameters. These
es are very useful for the inspection of machine
onents prior to assembly.

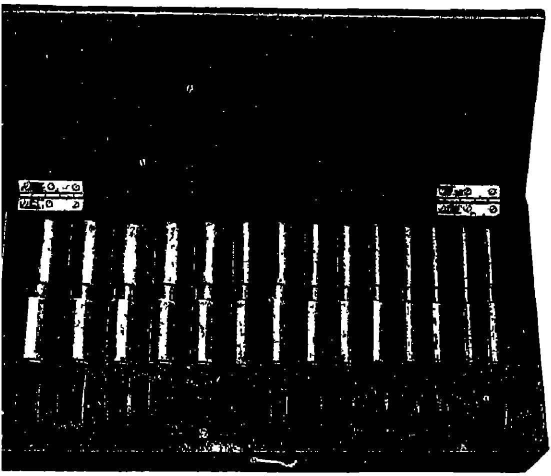

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FIG. 28.—TYPICAL SET OF PLAIN PLUG AND RING GAUGES.

ien the work is very near to the size of the
, a plug gauge may be forced into (or a collar
may be forced over) the work, but this should
be done. A plug gauge should never be
d into a hole, or a ring gauge over a spindle,
will not go without appreciable friction or
ance. If the size of the work is correct, the
will fit without perceptible play.

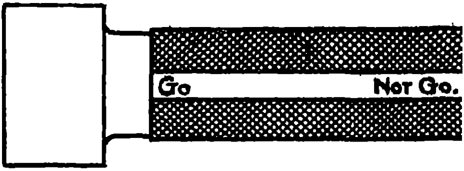

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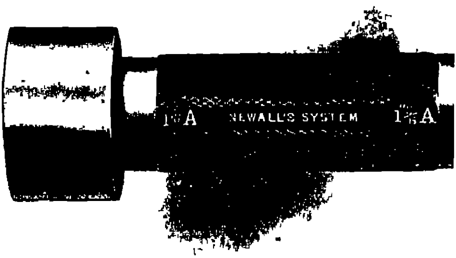
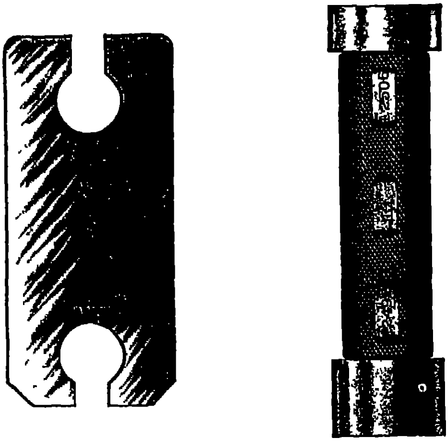
FIG. 29.—"GO" AND "NOT GO" PLUG



Newall]

FIG. 30.—NEWALL INTERNAL LIMIT GA
CLASS "A"

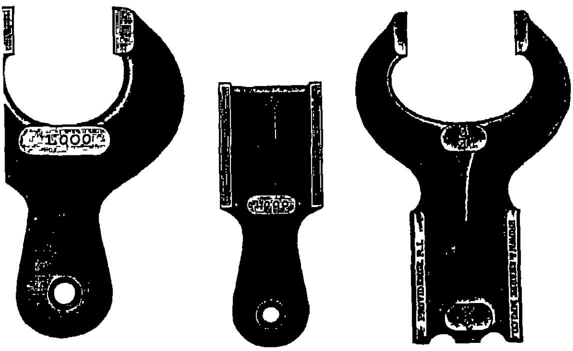
The long end is the "go" end which enters the hol
short end is the "not go" which must not en



Brown & Sharpe Mfg. Co

'IG 31.—EXTERNAL (LEFT) AND INTERNAL (RIGHT) LIMIT GAUGES.

Note the differently shaped ends, which facilitate identification of the larger and smaller ends without reference to the sizes stamped thereon



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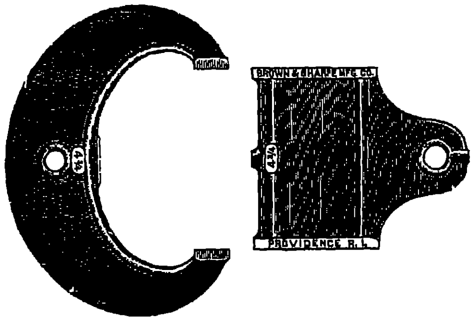
G. 32.—STANDARD CALIPER GAUGES FOR EVERYDAY WORKSHOP USE. *See also* FIG. 33.

iowing double-ended, external and internal pattern (right); also single-ended gauges (centre and left)

Limit Gauges.

A gauge of a very useful type, known as the "limit gauge," is shown in Figs. 29 to 31. With this type of gauge two fixed dimensions are provided, one being the "go" and the other the "not go." In use, the diameter to be gauged is to be such that the "go" dimension of the gauge will just slip over



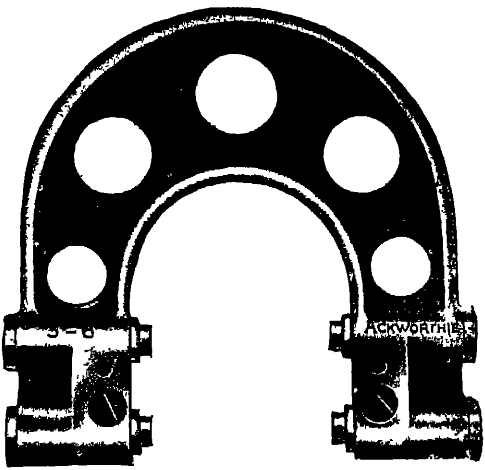
Brown & Sharpe Mfg Co

FIG 33 —STANDARD CALIPER GAUGES, SHOWING CONSTRUCTION ADOPTED FOR LARGER SIZES. (*Cf.* FIG 32).

or inside the work, and the "not go" dimension will not enter or pass over the work. As the difference between the two dimensions provided by the gauge may be extremely minute, it follows that work passed by this gauge can be made accurate to a very high degree. The actual difference between the "go" and "not go" diameters depends upon the "tolerance" allowed in the dimensions of the work to be checked (see Chapter VII)

Limit gauges are generally procurable in sizes ranging from ¼ in up to 6 in. Adjustable gauges

is type are also obtainable in which the precise nsions of the "limits" can be varied within in narrow limits. With this type of limit e the same instrument can be used for varying nsions of work and the extent of permissible tion of the work can also be altered at will.



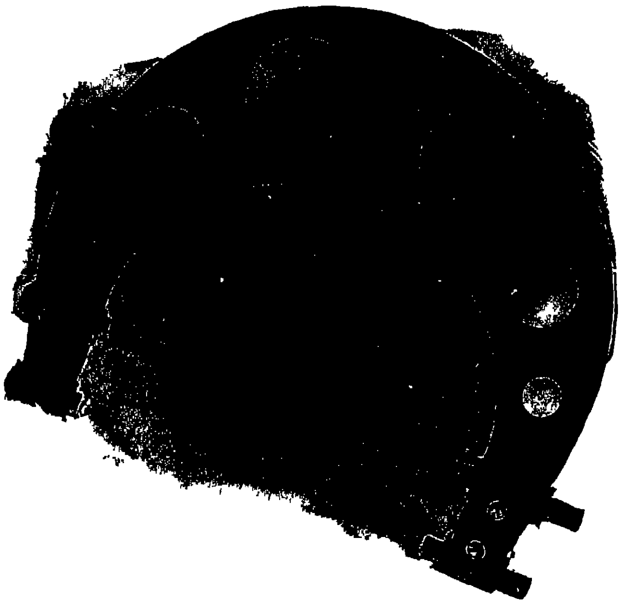
J Ackworthie, Ltd

FIG 34.—ADJUSTABLE PLAIN CALIPER GAUGE, HIGH AND LOW LIMIT

stable Caliper Gauges.

e ordinary type of limit gauge for outside work ot be adjusted for wear, and provides only one e of permissible error (corresponding to the ence between the "go" and "not go" eters). With this type of gauge the "go" inevitably becomes worn with use and its

accuracy is thus lost; wear on the "not go" end of the gauge is negligible. In use, therefore, this type of gauge permits an ever-increasing error,



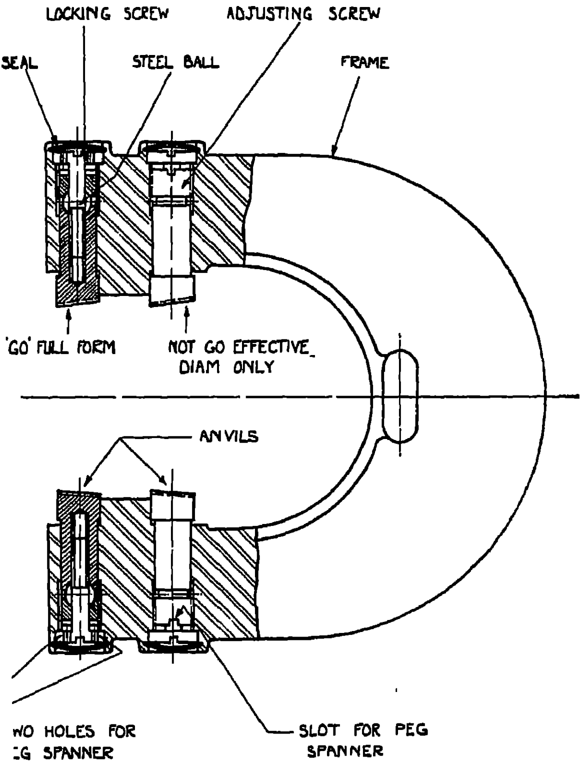
Newall Engineering Co

FIG. 35.—NEWALL ADJUSTABLE EXTERNAL LIMIT GAUGE.

Provided with two pairs of anvils which are quickly adjusted to the diameter and class of fit required

and though the rate of wear may be very slow, the gauge must ultimately become useless for accurate work and has to be scrapped.

A useful form of adjustable caliper gauge is shown in Fig. 34. The body is of malleable iron;



Alfred Herbert, Ltd.

36.—Showing the Construction of the Wickman Caliper Gauge with Threaded Anvils.

a special key is provided for the adjustment of the anvils, and the construction is such that adjustment can only be carried out by this means. The adjusting screws do not project from the body portion whatever the diameter to which the gauge is set to measure. This gauge is made in 18 sizes with a range of adjustment varying from 0 to $\frac{3}{4}$ in. up to 15 or 16 in. A larger adjustable gauge of the same general construction is shown in Fig. 35.

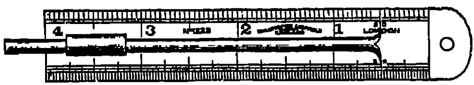
The adjustable Wickman caliper gauge is shown in Fig. 36. The tool illustrated is for gauging screws and other externally threaded work. The "go" anvils have full form threads; they ensure that the diameter of the screw is not too large and, being of sufficient width to give the required length of engagement, they also check the pitch. The "not go" (inner) anvils have only one or two threads, and these are cleared away at the root and at the crest, so that the threads come into contact only with the effective diameter of the screw, which is the element they are intended to control. If the pitch error in the screw be too great the effective diameter will have to be reduced to such an extent, in order to get the screw through the "go" anvils, that it will also pass through the "not go" anvils and therefore be rejected.

For the limit gauging of plain (not threaded) work, the general construction of the caliper is the same, but plain parallel anvils are used.

When used in combination with renewable-ended plug limit gauges this gauge is an ideal equipment for controlling all kinds of shaft and hole work. The

;e of adjustment on each gauge is ¼ in. in the ; up to 1½ in., and ½ in. in the larger sizes up 12 in The fractional difference between the " and the "not go" gauges can, of course, be rolled and regulated to any desired extent.

djustment of the anvils is made as required and locking mechanism is covered by a lead seal :h can be indented with the users' mark so that inauthorized alteration of the seal can escape ction.

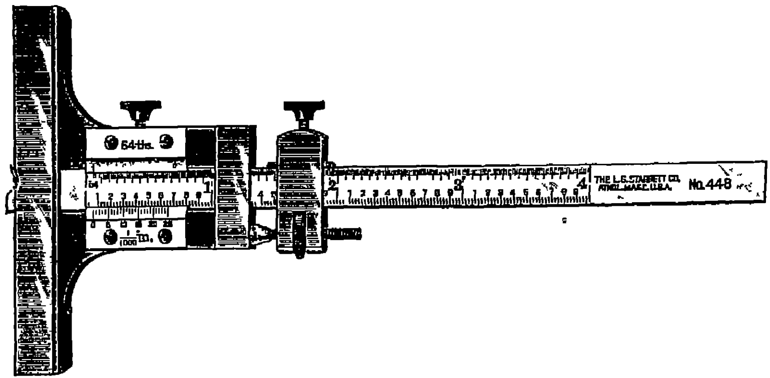


J Chesterman & Co , Ltd

FIG 37.—SIMPLE DEPTH GAUGE FOR DIRECT READING AT END OF SLIDING BAR

th Gauges.

'here it is necessary to measure with great iracy the depth of recesses or holes, as in jig die work, depth gauges are of great service. ts simplest form, the depth gauge consists of eel straight edge with a stout wire held in a ıve, at right angles to the axis of the straight ;, by a milled-headed nut. The depth of the or recess to be measured is obtained by setting wire and the extent of its projection from the ight edge is then ascertained by measurement. ıther forms of this instrument a graduated scale sed instead of the stout wire, and the depth is l off direct on the scale.



L S Starrett Co , Ltd

FIG. 38 —DEPTH GAUGE WITH VERNIER READING TO 1000TH INCH.

ı simple form of depth gauge is shown in Fig. 37 l a more elaborate design ın Fıg. 38. In the latter e a total depth of 4 in. can be measured to 4th ın. on one side of the scale and, by means of vernier, to 1000ths of an inch on the front of the le. The depth indicated by the gauge in Fıg. is ½ in., and that shown by the gauge ın Fig. 38)·060 in It wıll be seen that, in Fig. 38, the ɔ of the vernier scale is the same distance from measuring edge of the gauge as the zero on the le is from the end of the latter, the reading is, course, taken on the zero line of the vernier, *s* the vernier reading if any. A mıcrometer ıth gauge is illustrated in Fig. 54, p. 98.

le and Step Gauges.

\ gauge of this type is illustrated in Fig 39. e feet of the frame are placed on the surface m whıch the depth of hole or height of step is to measured, and the slıder is set to touch the bottom the hole or the top of the step as the case may be. e readıng on the centre-zero scale then gıves, at ɔe, the desired dımension.

p and Block Gauges.

\ typical set of these gauges is shown in Fig. and a few of their many applications are illus- ,ted in Figs. 41 to 44. The gauges are made in s of eight or multiples of eight, the various pieces each set being interchanged during the process

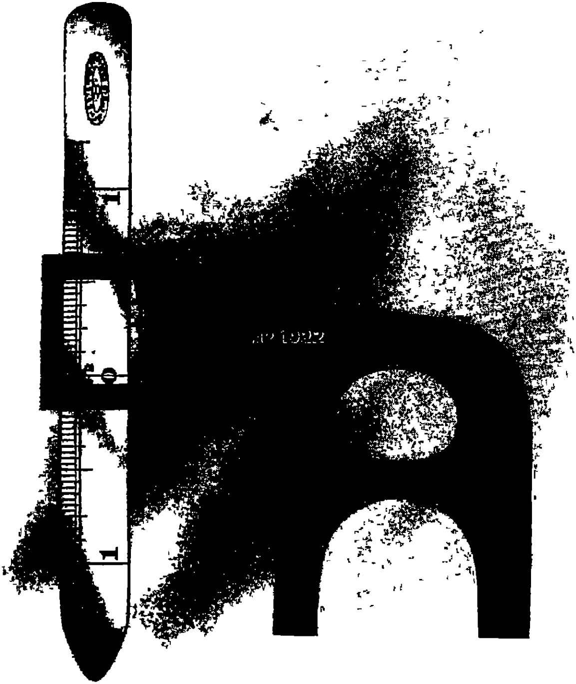


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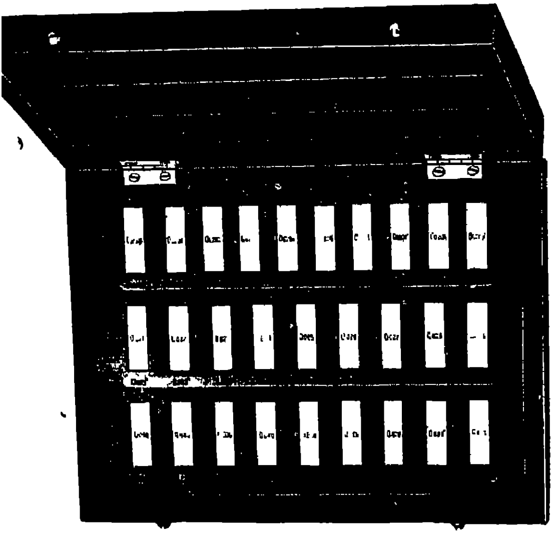
FIG. 39 —HOLE AND STEP GAUGE

ınufacture according to a definite programme*
ı ensures that all the pieces progress steadily
'ds an ever-higher degree of accuracy, both

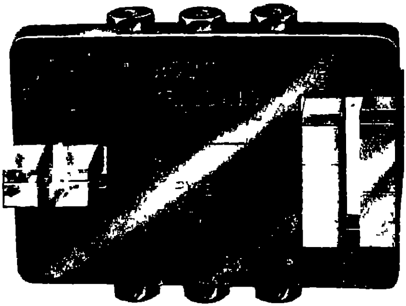


Pitter Gauge & Precision Tool Co, Ltd.

FIG. 40.—SMALL SET OF SLIP GAUGES

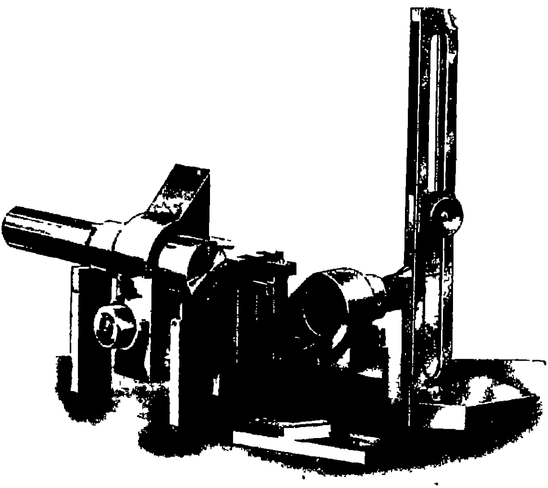
›gards size and parallellism of faces. It is
ıy of remark that the precision now attained
e manufacture of these gauges and in their
urement by the "generator comparator" (p.
, such that the greatest uncertainty in the whole
ıtion is that involved in determining the parent

etailed in a brochure entitled *Accuracy in Industry*, issued
ə Pitter Gauge and Precision Tool Co, Ltd, Woolwich,
'.



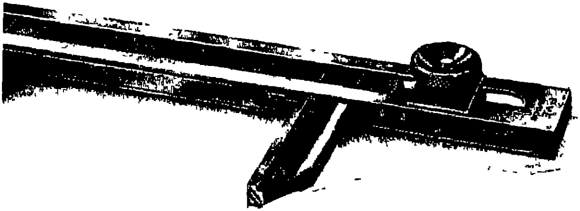
Pitter Gauge & Precision Tool Co., Ltd.

FIG 41 — TESTING LIMIT GAUGES BY MEANS OF SLIP GAUGES.



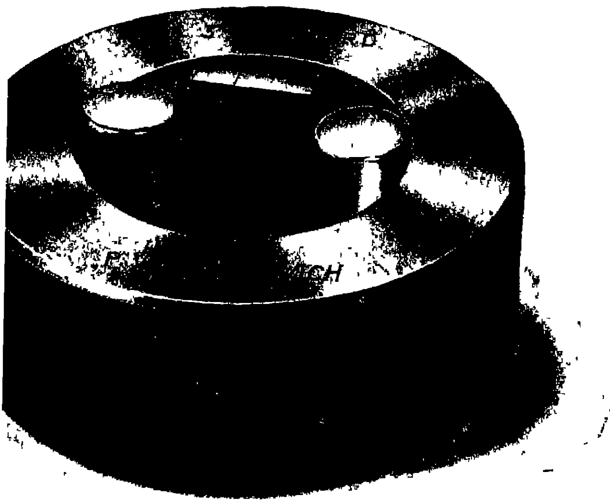
Pitter Gauge & Precision Tool Co., Ltd.

FIG. 42.—TESTING A JIG BY MEANS OF SLIP GAUGES AND HEIGHT GAUGE.



Pitter Gauge & Precision Tool Co., Ltd.

. 43.—HEIGHT GAUGE, 4-IN. JAWS, AND SLIP GAUGES SET UP TO TAKE A LENGTH MEASUREMENT.



Pitter Gauge & Precision Tool Co, Ltd.

FIG. 44.—SHOWING METHOD OF TESTING A STANDARD CYLINDER GAUGE BY MEANS OF CALIBRATED ROLLERS AND SLIP GAUGES.

end standard in terms of the fundamental line standard (the Imperial Yard). Once the parent bar is obtained the smaller bars, blocks, and slips are accurate subdivisions of the parent standard, the initial tolerance on which is distributed proportionately, according to length, amongst all the pieces generated from it.

Various sets of slip and block gauges are provided to meet different requirements, there being from 28 to 103 pieces in the set according to the increments and number of combinations required. A full set of English gauges comprises 81 pieces, viz., 9 from 0·1001 to 0·1009 by ten-thousandths of an inch; 49 from 0 101, by thousandths; 19 from 0·05 to 0·95 by increments of 0·05 in.; and the four sizes 1, 2, 3 and 4 in.

The use of slip gauges to test limit gauges is illustrated by Fig. 41. Slip gauges, used independently and in combination in a height-gauge frame, are employed for such purposes as checking jigs (Fig 42) The height gauge frame, in conjunction with slip gauges and special jaw pieces, offers a convenient method of measuring lengths in the workshop (Fig. 43). The use of combination end bars for the measurement of lengths up to 40 in. has already been described (see Fig. 12, p. 45). Though rectangular slips will not make face-contact with the interior of a ring gauge, the latter may be checked by a combination of slip gauges and calibrated rollers as shown in Fig. 44. The rollers for this purpose are calibrated against slip gauges by means of the "generator comparator" (p. 12).

CHAPTER IV

MICROMETERS

EN a screw is rotated through one complete ɔlution it moves, in relation to the part threaded t (e g. its nut) a distance equal to the "pitch" he screw, or in other words, through the distance veen two consecutive turns of the thread. This ance is generally a known quantity; if the tch" is not already known it can be determined means of gauges. A number of measuring ices are in use in which contact of the points, veen which measurement is made, is effected a screw adjustment.

rometer Calipers.

nstruments of this class are very extensively d in measuring the thickness of plates, diameters 'ods, and for many other purposes For protec- ı against dirt, grit, and mechanical injury they generally supplied in cases as shown in Fig.

In the usual form of micrometer calipers the ɔh of the screw is made small (generally 1/40th , and the screw has attached to it a thimble ing its circumference divided into a number of ıal parts (generally 25) The amount of move- nt equal to a fraction of a complete revolution rotation of the screw can then be determined l it is possible to read with great accuracy the tance through which the point of the screw,

forming one end of the measuring appliance, has moved.

The construction of a simple micrometer caliper and the manner of using this instrument may be explained by reference to Fig. 46. The spindle *C* is attached to the thimble *E* on the inside at the end, *H*. That part of the spindle which is concealed within the sleeve *D* and thimble *E* is threaded

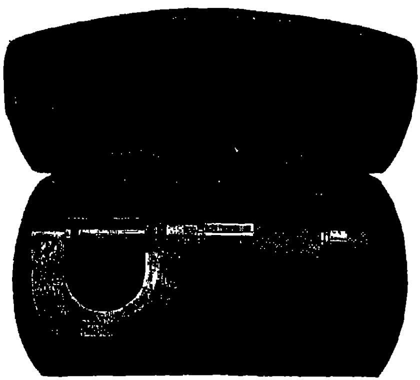


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FIG. 45.—MICROMETER WITH RATCHET STOP AND CLAMP RING.

to fit a nut in the frame *A*. The frame being held stationary, the thimble *E* is revolved by the thumb and finger, thus turning the spindle *C* in its nut, and causing *C* to approach or recede from the anvil *B*. The piece to be measured is placed between *B* and *C*, and the distance between the faces of the anvil and spindle is shown at any moment by the lines and figures on the sleeve *D* and thimble *E*.

ie pitch of the thread on the concealed part ie spindle is $\frac{1}{40}$ in., so that one complete revolu- of the thimble increases or decreases the ince between anvil and spindle by $\frac{1}{40}$ in. (0·025 Each division of the scale on *D* corresponds ne turn of the thimble, i.e. to $\frac{1}{40}$ or $\frac{25}{1000}$ in.

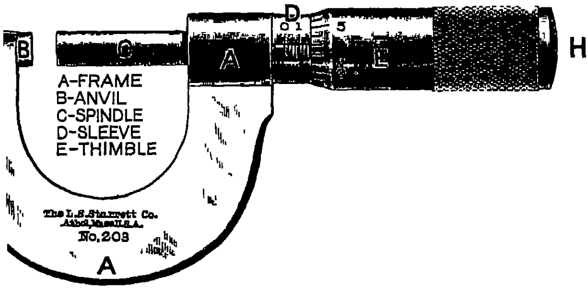

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FIG 46.—MICROMETER CALIPER READING TO 1000TH INCH.

numbers on this scale are four divisions apart, therefore indicate $\frac{4}{40}$ or $\frac{1}{10}$ in. The bevelled of the thimble is divided circumferentially 25 equal parts ; these are read against the line of the scale on *D*, and each division on rresponds to 1/25th of one turn of *E*, i.e. to h of 0·025 in. or 0·001 in. movement of the le towards or away from the anvil.

the setting illustrated by Fig. 46 the reading e micrometer is 1 on scale *D* (= 0·100 in.) three small divisions on scale *D* (= 3 × 0·025 *plus* three divisions on the thimble (= 3 × in.), or 0·100 + 0·075 + 0·003 = 0·178 in.

383)

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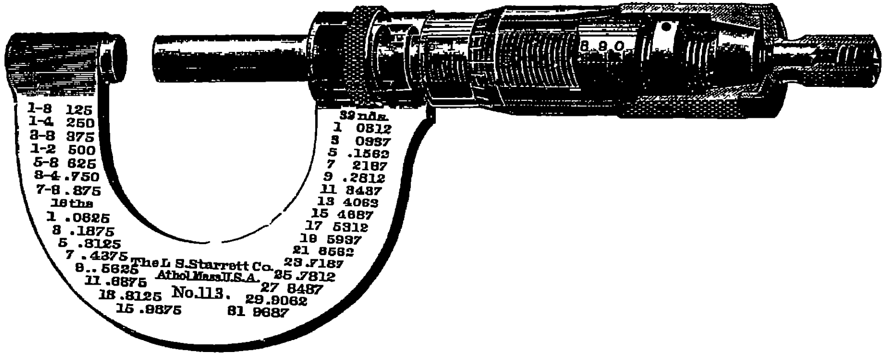

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FIG 47 —SKELETON VIEW OF THE MECHANISM OF A MICROMETER CALIPER.

'he skeleton view in Fig. 47 shows the internal :hanism of a Starrett micrometer with: (*a*) the irled locking nut which contracts a split bushing nd the spindle, keeping it central and true and ing it firm to make a solid gauge if desired; the ratchet head which enables the spindle

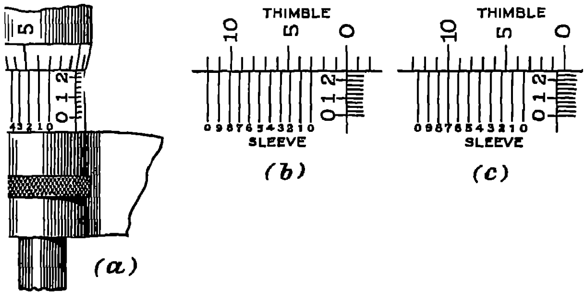

FIG 48—ILLUSTRATING METHOD OF READING A "TEN-THOUSANDTH" MICROMETER CALIPER

ys to be tightened on to the work to a uniform ee, thus making for accuracy by preventing rmation of the work and strain or wear on the

ecial forms of micrometer calipers incorporating dditional vernier are obtainable. With this of micrometer, ten lines equally spaced apart ngraved on the adjustable sleeve which occupy same space as nine of the divisions on the ble so that the difference of the spaces apart e lines on the sleeve is one-tenth of the distance of the lines on the thimble. The vernier fore gives a reading to a further place of

decimals or to an accuracy of one ten-thousandth of an inch.

The arrangement of scales on a "ten-thousandth" micrometer caliper and the method of reading them will be clear from Fig. 48. The illustration *a* shows the general appearance of the three scales on the actual instrument, while *b* and *c* show the "development" of the scales, i.e. their appearance if the barrel of the micrometer were cut longitudinally and laid out flat. In Fig. 48*b* we have two-tenths plus two small divisions on the main scale of the sleeve, i.e. 0·2 + (2 × ·025) or 0·25 in.; the reading on the thimble is zero and the vernier reading is also zero (the lines at each end of the vernier being exactly coincident with divisions on the thimble); the complete reading is, therefore, 0·2500 in in this case. In Fig. 48*c* the main scale reading is 0·25 in. as before, the thimble reading is 0 plus a fraction of one division; this fraction is read on the vernier and is seen to be 7 ten-thousandths of an inch (the 7 line on the vernier coinciding with one of the divisions on the thimble), the complete reading in this case is therefore 0·25 + (0 × 0·001) + (7 × 0·0001) or 0·2507 in.

(NOTE.—The thimble reading (thousandths of an inch) is taken on the axial line of the main scale of the sleeve and *not* opposite the zero of the vernier scale; in other words, the thimble reading in Fig. 48*c* is 0 thousandths plus the vernier reading, and *not* 3 thousandths plus the vernier reading.)

Micrometer calipers of the ordinary form are generally procurable to read in British measurement

ı 0 to ½ in., from 0 to 1 in., and from 0 to 2 in. netrıc measurement the usual sızes are from 13 mm., 0 to 25 mm., and from 0 to 50 mm.

ɔlementary Fittings.

number of ingenious devıces ensuring greater and accuracy of reading have been introduced ı time to time ; the more important of these be briefly noted.

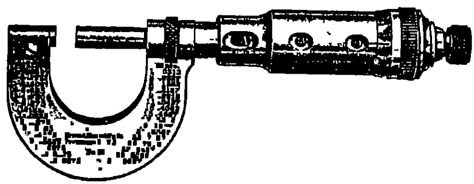

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FIG. 49 —DIRECT READING MICROMETER

ct Reading Micrometer.

ıe mıcrometer caliper shown in Fig. 49 enables sandths of an inch to be read in plain figures out the use of a vernier. The figures showing ıe opening nearest the frame indicate the movet of the spindle by tenths of an ınch. Those he next opening register the movement by lredths of an inch, while the figures in the last ing indicate the movement by thousandths. ıddition, the thimble on the end of the sleeve is uated in connection with a line on the sleeve ɔad to thousandths of an inch. By means of

these lines, fractional parts of a thousandth may be estimated.

The registering mechanism is so constructed that the dials are positively locked, and the micrometer cannot get out of adjustment and read incorrectly. The range of the instrument is up to 1 inch.

Quick Adjustment Device.

In using a micrometer caliper of the ordinary type it sometimes takes an appreciable time to open it the required amount for the particular measurement involved and to close it after it has been used and is to be put away in its case. Since there are 40 threads to the inch, forty complete revolutions of the thimble are required for opening or closing to an extent of one inch. This operation takes, say, 20 seconds, so that, in the course of a day, a considerable amount of time may be saved by the use of quick adjustment calipers. In these instruments it is only necessary to press with the finger against the end of the plunger in order to release the nut, disengaging it from the screw, and allowing any adjustment within the range of the calipers to be made instantly. On releasing the pressure, the nut engages again with the screw and the fine adjustments can then be made in the ordinary way.

Ratchet Stop.

Micrometer calipers can easily be strained if more than a certain amount of pressure be applied

he screw; possible overstraining is largely
ented by the provision of a ratchet stop in
h the ratchet slips by the pawl if too great a
ure be applied. The spindle is thereby pre-
ed from turning too far and possible springing
e instrument is avoided. Fig. 47 (p. 88) shows
ly the construction of this useful attachment.
device is particularly applicable when a number
neasurements have to be taken quickly and
cularly when the same instrument is used for
ng measurements by more than one person;
ne latter case the same amount of pressure is
in each case on the objects being measured.

ensation for Wear.

course of time wear on the screw and nut, on
nvil, and on the end of the spindle of micrometer
ers is inevitable. In some cases provision
de for this wear by allowing for the adjustment
ne anvil. A more satisfactory method con-
of the provision of a separate sleeve carrying
ase or zero line instead of having this line on
barrel which is rigidly attached to the spindle.
Starrett Company's instructions for using this
od of adjustment are as follows—
ke up the wear of the screw and nut, then
ve all dirt from the faces of the anvil and
le and bring them carefully together. Insert
mall spanner wrench in the small hole and turn
the line on the sleeve coincides with the zero
on the thimble.

Heavy Micrometer Calipers.

FOR special usages and for large scale work, numerous forms of heavy micrometer calipers have been introduced. Standard forms of these instruments, to read either in British or in metric measurement can be obtained, having ranges of from 1 to 2 in. up to from 11 to 12 in., and from 25 to 50 mm.

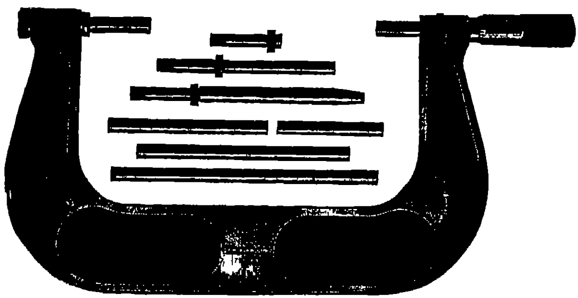

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FIG 50.—MICROMETER CALIPER FOR MEASURING PISTONS.

up to from 275 to 300 mm. The spindles and the screwed portions are of larger area than in the case of the ordinary form of micrometer calipers.

The micrometer caliper shown in Fig. 50 is designed specially for measuring pistons in motor service work. Its range of measurement from 2 to 6 in., by thousandths of an inch, covers all pistons ordinarily used.

This range of measurement is obtained by the four anvils furnished with the micrometer. These anvils are easily and quickly changed, and held positively in place by a knurled nut. One anvil is

· measurements from 2 to 3 in., another from ,o 4 in., and so on.

In the Slocomb micrometer caliper (Fig. 51) the ιding line on the barrel ιs divided into forty parts r inch, corresponding to the pitch of the screw. ι one side of the line these are grouped ιn fours mbered from 1 to 10 in the usual way (tenths of

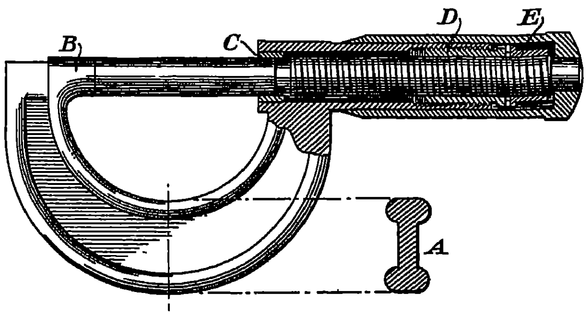

FIG 51 —THE SLOCOMB MICROMETER CALIPER.

inch), and on the other side of the line they are ɔuped in fives, thus indιcating eights of an inch. ιcιmal equivalents are stamped on the thimble. e tool can be set by eights without any calcula- n or it can be used just as readily by decimals in ɘ ordinary way. The frames are of drop-forged .el of the section shown, and the range of the iper is 1 inch, the maximum size being from 1 to inches as required.

ecial Forms of Micrometer Calipers.

For the measurement of the pitch diameter of 'ew threads (i.e. the overall diameter of the screw

minus the depth of one thread), micrometers are supplied in which the spindle is pointed and the anvil has the same form as the thread to be measured.

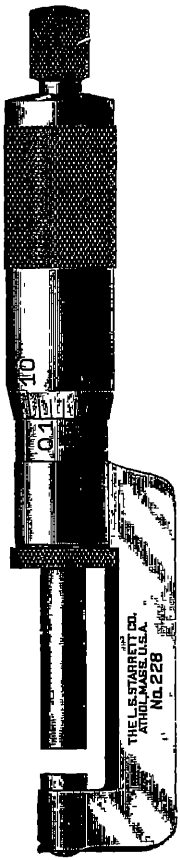

FIG 52 —HUB MICROMETER CALIPER, WITH SPECIALLY NARROW FRAME

L S Starrett Co, Ltd

Where space is confined the frame of the micrometer may be cut away behind the anvil so that the width over the latter is a minimum (say $\frac{1}{4}$ in.); or the whole frame may be given a rectangular form, as in Fig. 52, so that the tool can be passed through, say, the bore of a milling cutter to measure the hub length, or through a bolt hole to measure the thickness of the adjacent plate.

On the other hand, it may be desirable to use a micrometer the frame of which has a specially deep throat so that a measurement can be taken well away from the edge of a plate. For the measurement of tube thicknesses, a rounded anvil should be used; this touches the inside of the tube at only one point, whereas a flat anvil would lie on a chord of the circle, thus causing the reading of the micrometer to be greater than the

ckness of the tube. In measuring the thickness paper, rubber, or other soft material, discs about n. diameter may advantageously be fitted to ; spindle and anvil, so that a reliable reading can taken without compressing the material measured. Γhe micrometer caliper shown in Fig. 53 is ;cially convenient for measuring sheet metal.

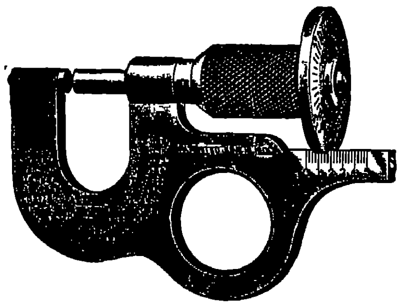

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FIG. 53.—MICROMETER FOR MEASURING SHEET METAL

placing the middle finger of the right hand 'ough the ring, the caliper is held at right angles the sheet to be measured and readings made while this position. The thimble is operated by the efinger and thumb of the same hand. To facili- e the readings of the caliper while held in position, ; one-half thousandth readings are taken from the l at the top of the spindle, the readings being icated by the pointer, and the twenty-five ›usandths readings, or those corresponding to ; readings on the barrel of an ordinary micrometer

caliper, are taken from the scale at the top c
frame.

The decimal equivalents stamped on the

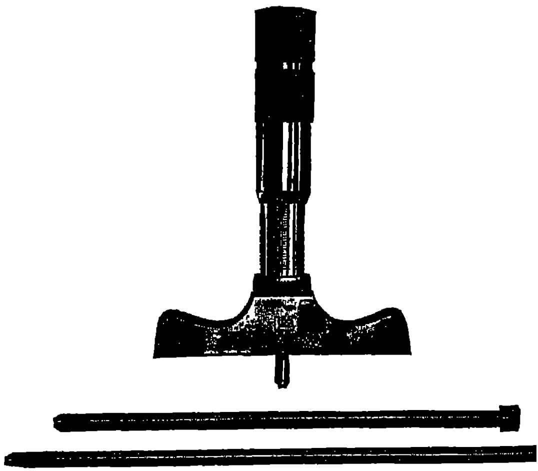

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FIG 54—MICROMETER DEPTH GAUGE.

are convenient and render possible the imm
expression of readings in 8ths, 16ths, 32nd
64ths of an inch. When calibrated in E

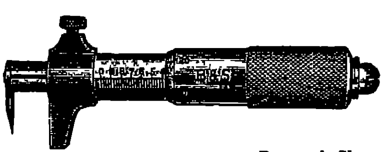

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FIG. 55.—SCRIBING MICROMETER FOR SETTING O
DEPTH OF GEAR TEETH, ETC

measure the tool measures all sizes up to 1
half-thousandths of an inch (0·0005 in.) and q

usandths are easily estimated. The caliper is ɔ made to measure up to 13 mm. by hundredths ı millimetre.

[he use of depth gauges has already been exımed (p. 77), and a micrometer gauge of this)e is at once convenient and accurate. The :rometer screw in the gauge shown in Fig. 54 ; a movement of 1 in. and the range of 0 to 3 in. ɔbtained by the use of the three measuring rods nished. The desired rod is easily and simply erted in the gauge through a hole in the crometer screw.

Γhe scribing micrometer illustrated in Fig. 55 is signed for scribing a line on gear blanks to indi;e the extreme depth to which the teeth are to cut. In this service it is specially economical that it avoids the necessity for keeping a large mber of separate gauges for different pitches. ıe tool is also handy as a scratch gauge for scribing es and measuring spacing within its range, viz., ı to 1 in. by thousandths, or up to 25 mm. by ındredths. A clamp screw is provided for clampg the spindle and preserving the setting.

Micrometer heads, such as that illustrated in g. 56, can be attached easily to tools or machines hen fine measurements are required, and the inside icrometer caliper set, shown in Fig. 57, is designed r internal and linear measurements, e.g. measuring ʼlinders and rings, setting calipers, comparing ıuges, measuring parallel surfaces, and so forth. he micrometer screw in the head has $\frac{1}{2}$ in. or 1 in. ovement, as required, and, by means of the

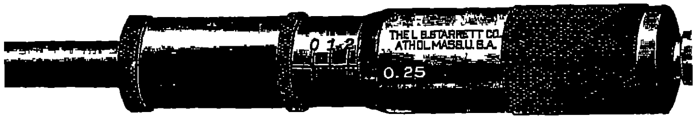

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FIG. 56.—MICROMETER CALIPER HEAD READING TO THOUSANDTHS OF AN INCH.

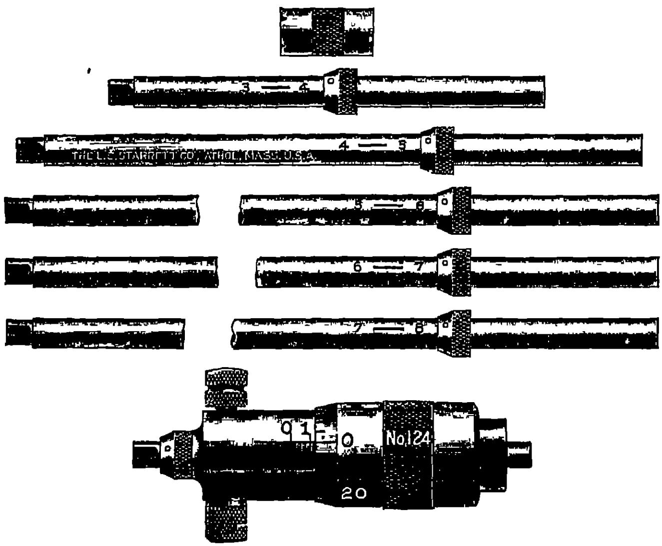

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FIG 57.—INSIDE MICROMETER CALIPER SET.

nsion rods, measurements can be made from . up to 32 in.

any other applications of the micrometer suring screw might be mentioned, but enough been said to demonstrate the utility of this ce and the general manner of its use.

CHAPTER V

MARKING OFF

Surface Plates.

The "surface plate" is a metal plate having a true flat surface and is used as a test plate for other surfaces. It is used extensively in the various operations of marking out, laying out, and testing work, and, in particular, in the various operations incidental to the preparation of work for machining. Surface plates are made of cast iron, or, alternatively, of hardened cast steel. Ordinary cast iron surface plates are surfaced with files and scrapers; chilled cast iron and hardened cast steel surface plates have their surfaces ground, since they cannot be satisfactorily cut with steel tools. Until comparatively recent years a chilled or hardened surface plate could not be surfaced so truly as one finished by filing and hand scraping, but the great improvements in grinding machinery of recent years* have enabled the hardened surface plate to be now produced to a high degree of accuracy.

The production and use of a true plane surface is inseparably associated with accurate machine shop work and precision measurements. This fact is easily appreciated, but it is not always realized that anyone possessed of patience and a reasonable degree of manual skill can "originate"

* See also *Grinding Machines and their Use*, by T. R. Shaw. (Pitman's Technical Primer Series, 2s. 6d. net.)

ıce plates by Whitworth's method. If one ıce plate be avaılable another can be made to ı, but Whitworth's method enables one to start ı three rough castings and to derıve therefrom e surface plates accurate to the highest degree ınable by a skılled craftsman. The procedure 'oadly as follows: One paır of plates is planed, hıpped and filed, untıl the surface of each is,

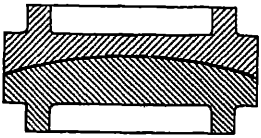

FIG. 58.—THE FACT THAT TWO PLATES FIT IS NO GUARANTEE THAT THEY ARE PLANE

narily speakıng, "flat." The surfaces are then ɔed together, usıng red lead to mark the high ıs, and the latter are removed by means of a per untıl finally the paır of plates bed perfectly on the other. Though these plates bed perfectly e is no guarantee that they are truly plane, for mıght be concave and the other convex to ɔtly the same curvature, as shown exaggerated 'ig. 58. The third plate is now worked up until ɔeds perfectly on plate No. 1. Fınally, the 3 plate is tried wıth the No. 2 plate—if ıt fits ectly, then all three plates are truly plane; versely, if all three plates be not truly plane, ı it ıs ımpossible for No. 1 to fit No. 2, No. 2 t No. 3, *and* No. 1 to fit No. 3. The reason for

this is evident from Fig. 59; Nos. 1 and 3, both being convex, fit the concave No. 2 plate, but Nos. 1 and 3 will not fit each other.

In practice it would obviously be wasteful of time and labour to bed two of the plates perfectly only to find from the third surface, that they were not plane. The actual procedure adopted is one which brings all three plates progressively nearer

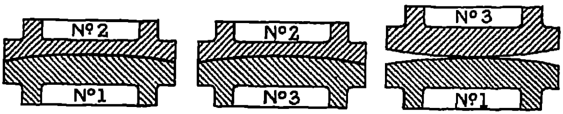

FIG 59.—THREE PLANES WHICH ARE NOT PLANE CANNOT FIT IN ALL COMBINATIONS

to a true plane. W. H. Pretty's cycle of operations, as quoted in *Mechanical Engineering** is as follows—

The plates are stamped with numbers (1), (2), (3), in conspicuous places, and the planing tool marks are eliminated with a smooth file. Then—

(1) Using (1) as a standard: bed (2) to (1); (3) to (1); and (2) to (3), working equally on each.

(2) Using (2) as a standard: bed (1) to (2); (3) is already bedded to (2); then bed (3) to (1), working equally on each.

(3) Using (3) as a standard: bed (2) to (3); (1) is already bedded to (3); then bed (1) to (2), working equally on each.

(4) Using (1) as a standard: bed (3) to (1); (2)

* By W. J. Lineham (Chapman & Hall)

'eady bedded to (1) ; then bed (2) to (3), working .lly on each.

us cycle of operations is repeated until sufficient racy is obtained.

raight edges may be originated in similar ner, and when these are being worked up they ld be reversed end for end occasionally, so as iminate all possible errors.

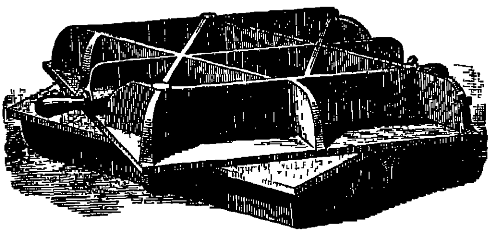

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FIG 60 —STANDARD CAST IRON SURFACE PLATES.

st iron surface plates are generally procurable zes ranging from 4 in. by 3 in. up to 36 in. by ; these plates can be obtained guaranteed 'ate to 1/1000th in., but are actually finished to nsiderably finer degree of accuracy. In the ıanically finished surface plates two grades ish are normally available, the first grade being ınteed accurate to 1/5000th in. and the second ə to 1/1000th in. The latter are suitable for ıary workshop use and the former are generally oyed for special purposes. The cost of Grade ıtes is usually about 50 per cent more than that 'ade B plates.

pical surface plates are shown in Fig. 60.

The shape of a surface plate is of very great importance, since any sheet or bar of metal tends to deflect from its normal outline consequent on its own weight or the weight of any body placed upon it. Also, in the case of a casting, if the form of the plate be not chosen carefully there may be internal contraction stresses in the metal which will result in warping, particularly under conditions of variable temperature.

To overcome these difficulties the body of a surface plate is heavily ribbed, the ribs being arranged to be of equal lengths and equal in thickness to that of the plate itself Under variations of temperature the ribs will not then expand or contract more than the body of the plate, and the warping which would accompany unequal expansion is avoided.

Ordinary surface plates are generally provided with handles for lifting (see Fig. 60) ; wood covers for the protection of the surface of the plate from accidental injury are also obtainable as a standard article.

Angle surface plates are procurable in a variety of forms and dimensions and are used in conjunction with a flat surface plate. Angle plates of this type are used in a considerable variety of ways where it is necessary to true a surface standing at an angle to another surface.

Scribers and Scribing Blocks.

The scriber is a steel tool with a hardened point or edge which is used to mark centre lines, profiles, etc

ıetal or wooden parts as a guide to subsequent ıining or other operatıons.

e ordınary form of hand scriber is a very simple · consisting simply of a length of steel rod with ırp and hardened point. Mechanics frequently r to make up their own scribers and innumer- forms are to be seen in regular daily use, the n, in most cases, being according to the fancy ingenuıty of the ındividual user. For those prefer a more elaborate article, many specıal s of scrıbers are obtainable. Most of these provided with a special knurled stock, to give n hand grip on the tool. Others are furnished points at each end of the stock, one being ıe ordinary straight form and the other being at right angles to the axıs of the tool. The r type of point is very useful for certain classes ork, as, for ınstance, in reachıng through holes other inaccessible positıons. Pocket scribers hich the scribing tool is carrıed in a body on of the ınstrument when not in use are also ınable in various forms.

ıs often necessary, when laying out work, to e lines at a predetermined heıght from some of the work, or to continue lines over the ıus faces or surfaces In effecting this a surface e is generally used, this beıng essentially an ument wıth a heavy base carrying a pıllar hıch a scriber is attached by a clamp which ıits ıt to be adjusted vertically and horizontally. simple form of surface gauge is shown in Fig. ınd a more elaborate gauge of this type in

Fig. 62. In the instrument shown in Fig. 61 the spindle has a vertical movement and the base is cut out so as to permit of the instrument being used as a depth gauge. For fine adjustment the spindle in the base is raised or lowered by a knurled nut and all backlash is taken up by a spiral spring in the base. An extension can be coupled to the spindle for lengths greater than 12 in.

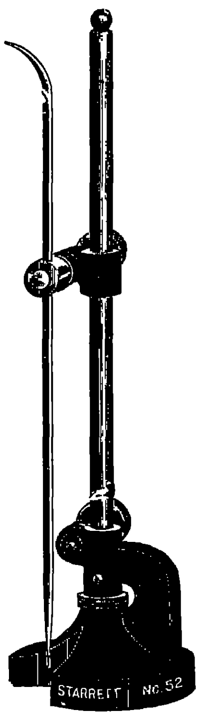

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FIG 61—SURFACE GAUGE WITH SPINDLE HAVING VERTICAL MOTION ONLY

Several varieties of this type of gauge are available in which the spindle is provided with a rocking bracket at its base so that it may be set either upright or at any desired angle, or it may be turned so as to permit of the scriber being used at a level below that of the base of the instrument. For example, in the instrument illustrated by Fig. 62, a wide range of adjustments can be readily made by means of the knurled adjusting screw. The spindle and the bolt and bushing through which it passes are locked in the position of approximate

ıstment by the knurled nut at the boss on the ›. The fine adjustment can then be used to ɩin the exact setting.

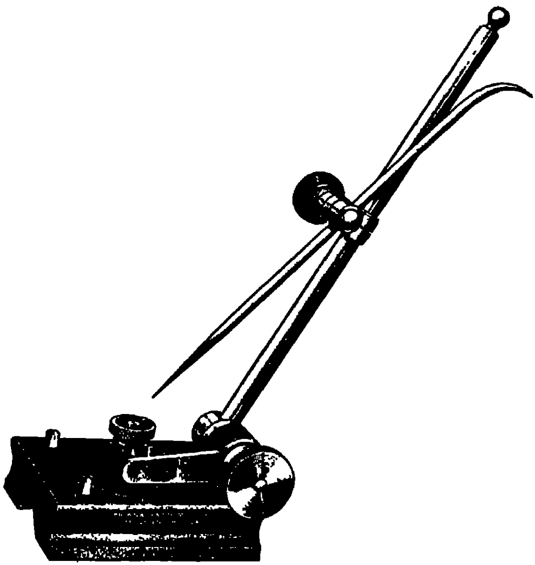

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FIG. 62 —UNIVERSAL SURFACE GAUGE.

'he base has Vee-groves in the bottom, so that tool can be used against circular work as well lat surfaces The two gauge pıns in the rear end ,he base can be pushed down and used against the e of a plate or the sıde of a T slot. The spindle vels, can be securely clamped in any position n the vertical to the horizontal, and the scriber y be used below the base as a depth gauge. For

small work the spindle may be removed and the scriber inserted in a hole in the spindle swivelling bolt, where it is readily adjusted. This type of instrument is obtainable in sizes ranging from 4 in. to 18 in. lengths of spindles, and is in every way a valuable aid to accurate workmanship.

Straight Edges.

Straight edges are employed for testing the straightness of a surface in one direction only, and

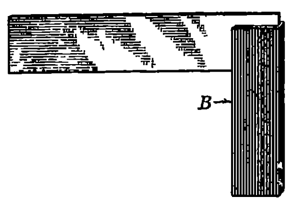

FIG. 63.—STEEL TRY SQUARE.

for scribing straight lines. They are obtainable with a plain rectangular section and also with one bevelled edge. In other forms, straight edges are graduated along one or both edges on one side with British standard or with metric scales They are usually procurable from 12 up to 72 in. in length, 1 in. up to $3\frac{1}{2}$ in. wide, and from $\frac{3}{16}$ up to $\frac{3}{8}$ in. in thickness. In metric measurement they can usually be obtained in sizes corresponding approximately to the above measurements.

Set or Try Squares.

The set, or try square, in its simplest form, consists of a rectangular back *B* (Fig. 63) holding a

ɘ, the edges of the back and of the blade being right angle to one another and truly straight. enerally used by a mechanic, the set square is ıge to test whether one face of a piece of work ds truly at a right angle to another face. In the block *B* is bedded truly against the work, the blade is brought to touch at some part ıst the face to be tested.

the majority of set squares the blade is finished ι; in some cases, however, the blade is engraved a scale graduated either to British or to metric surement. Set squares are generally obtainable zes varying from 1 in. length of block and 1 in. ,h of blade, up to 12 in. length of block and . length of blade.

bination Squares.

ıny special forms of squares are now available pecial and general purposes. Typical examples ιe most generally useful of these appliances are ʼn in Figs. 64 and 65. These instruments can sed for all purposes where an ordinary try or quare is used, but differ from the usual form ɿuare in that the head can be caused to slide ʒ the blade and can be clamped at any desired ıon. A spirit level and a mitre block are com-d with the square and a scriber is held frictionally e head in a small brass bushing. The set shown ig. 65 includes a protractor head with a level ;he back) at right angles to the one on the re.

The combination square can be used as a simp rule, square, mitre, depth gauge, height gauge ar

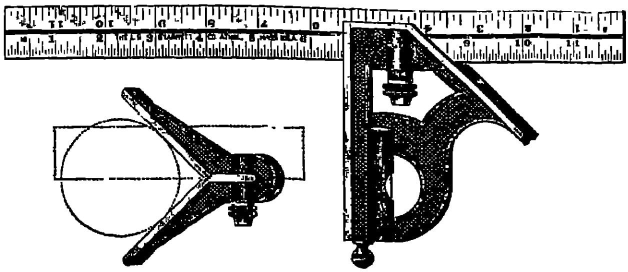

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FIG 64.—COMBINATION SQUARE.

level ; and, with the auxiliary centre head, it forr a centring square for both inside and outside wor

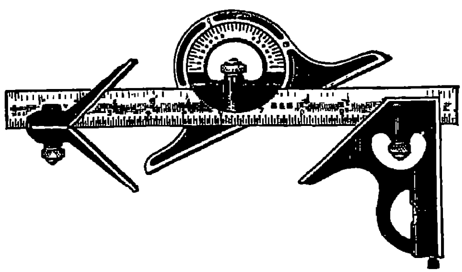

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FIG. 65.—COMBINATION SET ; ENGLISH, METRIC, OR ENGLISH AND METRIC.

In its ordinary form it is procurable in sizes of fro 4 to 24 in. length of blade.

vel Protractors.

For the measurement and setting out of angles general (not necessarily right angles), bevel ɔtractors are used. In its simplest form the bevel ɔtractor consists of a blade provided with a slot which a stud carrying the stock or back is located. ιe stud is usually locked in any desired position by ᵊans of a thumb screw and nut. Many forms of

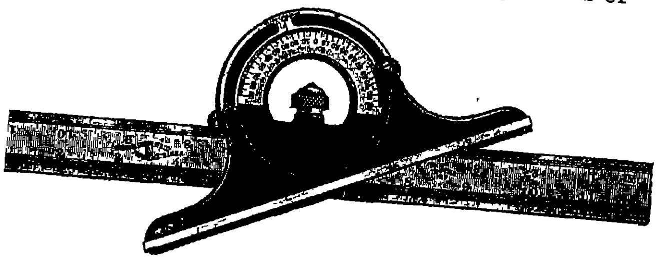

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FIG 66.—PROTRACTOR WITH REVERSIBLE HEAD; ENGLISH, METRIC, OR ENGLISH AND METRIC.

vel protractors are obtainable with which work of high degree of accuracy can be carried out. In me cases the scale of angular measurement is ovided with a vernier so that the instrument can set or can be read with very great accuracy.

Fig. 66 shows the use of a reversible protractor ad on a rule which is graduated in English, ɘtric, or English and metric units; a spirit level fitted on the reverse side of the head. The iversal bevel protractor shown in Fig. 67 is usel for all classes of work where angles are to be laid t, and with the acute angle attachment shown in

Fig. 68 very small angles can be established q
and easily. In both of the appliances illustrat
Figs. 67 and 68 one side of the tool is flat
allowing it to be laid flat on the work. The
graduated in degrees for the entire circle,
vernier reading to 5 minutes (5′ or $\frac{1}{12}$ of 1°) g
increases the accuracy of measurement. Fi
justment is provided by means of a small

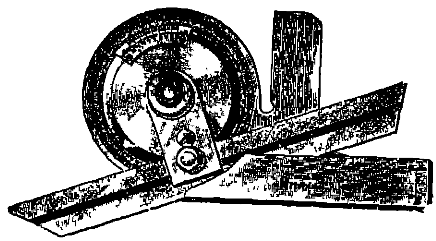

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FIG. 67.—UNIVERSAL BEVEL PROTRACTOR WITH VERNIER.

screw which is furnished as an attachment.
blade can be moved to and fro, throughc
length, and clamped independently of the dial

The principle of the angular vernier is id
with that of the linear vernier already des
(p. 38), and the manner of reading it will be o
from Fig. 69. Each space upon the vernie
minutes shorter than two spaces on the true
When the line marked 0 on the vernier co
with the line marked 0 on the true scale, the
of the base and blade are parallel. When the
head is moved so that the line on the vernier

ɔoincides with the line next but one to O on the e scale, the included angle of the base and blade ; been changed one-twelfth of a degree, or 5 nutes

Γo read the protractor setting, read off directly m the true scale the number of whole degrees

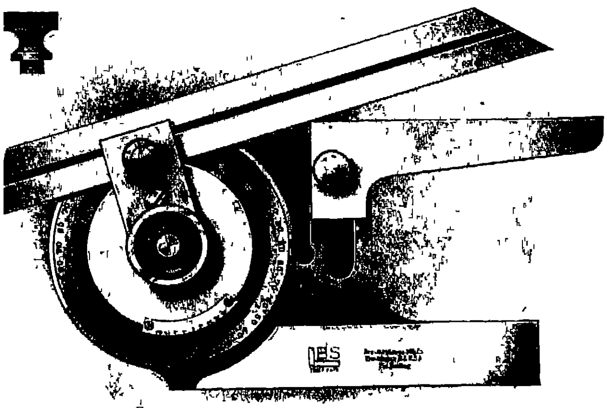

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FIG 68 —UNIVERSAL BEVEL PROTRACTOR WITH VERNIER AND ACUTE ANGLE ATTACHMENT

ɔtween O and the O of the vernier scale. Then ɪunt, *in the same direction*, the number of spaces ɔm the O of the vernier scale to a line that coin-des with a line on the true scale ; multiplying this ımber by 5, the product will be the number of inutes to be added to the whole number of degrees.

EXAMPLE —As the vernier is shown in Fig 69 it has moved ! whole degrees to the right of the 0 upon the true scale, and ıe eighth line on the vernier coincides with a line upon the

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true scale as indicated by *. Multiplying 8 by 5, the product, 4 is the number of minutes to be added to the whole number degrees, thus indicating a setting of 12 degrees and 40 minut (12° 40′).

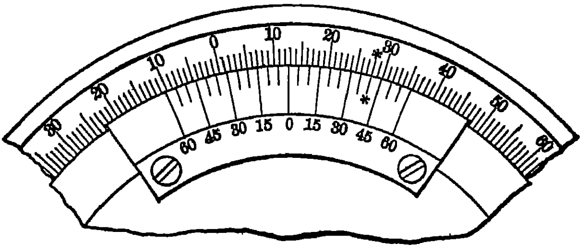

FIG 69 —ILLUSTRATING METHOD OF READING AN ANGULAR VERNIER.

The draughtsman's protractor shown in Fig. 7 is a simple but useful instrument which can be s

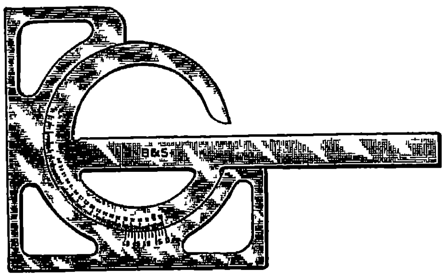

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FIG. 70 —DRAUGHTSMAN'S PROTRACTOR WITH VERNIER READING TO 5 MINUTES.

quickly to any angle, and used either side up and c either of the two outside edges of the frame. : can be used to advantage in dividing a circle, tran ferring angles or laying off a given angle, withou resetting, on either side of a line. In the drawir

ce this protractor forms a convenient extension a T-square and frequently takes the place of and 60° set squares.

l Test Gauge.

:he dial test indicator (Fig. 71) is of great assist-e in determining the accuracy or otherwise of a

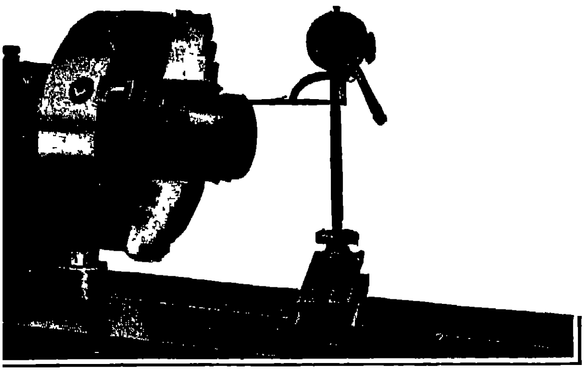

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FIG. 71 —DIAL TEST GAUGE FOR USE ON SURFACE PLATES AND THE LIKE

, surface or of the movements of a spindle, arbor, . The movement of the measuring surface that ırs upon the work is magnified a number of times l indicated by the pointer on a dial, which reads thousandths of an inch (or hundredths of a milli-tre), and is adjustable to allow the zero to be set any required position. The spindle has ¼in. (or ım.) movement.

The arm carrying the indicator can be removed from the post and used independently, as in the tool post of a lathe, and the measuring point is removable to allow the use of different forms. As shown in Fig. 71 the indicator is used in conjunction with an attachment which consists of a bracket carrying a pivoted lever, one end bearing on the measuring point of the indicator and the other on the surface investigated. This attachment enables the dial indicator to be used in testing internal and other surfaces which cannot conveniently be reached by the straight spindle of the indicator itself.

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CHAPTER VI

SELECTION AND CARE OF INSTRUMENTS

of the first importance that a mechanic desirous ıalifying himself for efficiency in high class work ıld possess a set of instruments which will ›le him to take measurements of all kinds with ;h degree of precision. The accuracy of measure-t to be realized will vary to some extent with nature of the work upon which he is engaged, ınstruments of precision are a prime necessity 7ery case and to every mechanic.

ι all cases it should be remembered that a ıvely few, carefully selected and well kept 'uments or tools, of the best workmanship design, will be of far greater practical value ı a larger assortment of miscellaneous " gadgets " oubtful accuracy and indifferently kept. Well-t, accurate instruments are generally expensive ıe first place, and they are only of practical value ɔng as they are properly looked after.

ction.

ι no case should a heterogeneous collection of ›ellaneous instruments be purchased ; each tool ıld be selected individually after the complete ;e of work to which it is to be applied has been fully considered. Advice from experienced ƨers is helpful and should always be listened to, it is generally a mistake to follow others' advice

too slavishly. In the use of workshop tools anc measuring appliances the personal factor enter largely into consideration. The correct attitud for the young mechanic in this connection is to lear all that there is to know regarding the experience of others, and to apply this to his own persona peculiarities and needs He should, in fact, cultivat the habit of considering all the conditions of wor for himself with a view to coming to a definit decision as to what will meet his own persona requirements.

The procedure in general should follow broadl the following lines.

(1) The conditions for which the instrument i required and all the purposes to which it will b applied should be passed in review and noted dow in writing.

(2) The best type of tool, i.e. the design be suited to the full range of requirements should the be decided upon.

(3) The fullest information from all sources shoul be obtained, and the various makes of this particul instrument should be investigated thoroughl Manufacturers' lists are very helpful in this conne tion, but should not be taken as the only guid they should be supplemented by a certain amou of advice from more experienced workers and al by the would-be purchaser's own mechanical kno ledge, as well as by a study of his own person experience.

(4) The instrument should be selected fro stock if possible, but in any case the deal should n

nally closed until the intending purchaser has
dled the goods, and satisfied himself that it
s his own personal requirements as regards
it of work to be covered and limits of accuracy
e attained.

many cases the deciding factors as regards
rent makes of similar tools are (1) soundness of
n, (2) quality of material, (3) fineness of
manship, (4) range of measurements. As
rds wearing or lasting qualities, apart from
ers' guarantees, it is necessary to rely to a
iderable extent on the experience of others,
in this connection it is important to remember
ultimate accuracy of workmanship is contingent
hese points.

many cases, workshop instruments are pur-
ed from fellow workers, but it is false economy
ly instruments in this way simply because they
heap In all such cases the intending purchaser
; ask himself firstly, does the instrument fulfil
ctual requirements, and, secondly, is it capable
ving consistently accurate results? Inaccurate
are a constant source of disappointment and
in no case give good results as regards finished
:.

is not possible within the space of the present
: to give any tabulated list of the tools or
uments which a mechanic should possess,
: such lists would have endless variation accord-
to the precise nature of the work upon which
mechanic is engaged. He should in all cases
pile his own lists, and should do so only after

very careful consideration on the lines rougl laid down above. The assembly of a good tool should be a gradual process of building up, and t guiding principle should be that the best is inevital the cheapest.

Care of Tools.

Nothing indicates slovenliness and inefficier in a workman more readily than the presence his tool kit of dirty, rusty, and damaged to(This is true of tools as used for general purpo and doubly so when applied to workshop gau and measuring appliances, since the sole justificat for the existence of such instruments is their cl approximation to absolute accuracy. If an ordin tool is not in perfect condition it may still be m to serve some useful purpose in skilful hands, the damaged or inaccurate gauge or measur appliance must either be put aside immediately damage or inaccuracy is discovered and must duly repaired, or the instrument must be scrap and broken up immediately. The presence defective instruments in a mechanic's kit m and frequently does, lead to costly mistakes workmanship as a result of their use.

Workshop gauges and measuring appliances m therefore be looked after most carefully. T must never be left lying about or kept loosely haphazard amongst other tools. When not actu in use they should be kept packed away in s special and properly designed receptacle, should taken out and handled only when actually nee

,he work in hand, and should be used with the ,test possible care and discrimination, all forcing rough handling being scrupulously avoided. y should always be wiped over with a clean oily rag immediately after use, and should be rned to their case or permanent resting place, never left lying about on the working bench.

odic Tests for Accuracy.

he frequency of tests for accuracy will largely end on the extent to which instruments are in In all cases they should be gauged for accuracy ntervals of, say, every four weeks, and should ,ddition be tested immediately before engaging ny work of special importance where the highest sible degree of accuracy is essential. It is not essary to lay down rules for the testing of each vidual type of workshop instrument, but certain ninent causes of possible inaccuracy may be itioned briefly.

es.

part from extreme variations of temperature, l rules are not liable to become inaccurate in except as regards "end" wear, that is, the lual wearing away of the two ends of the rule a result of prolonged use. With the modern e of hardened steel rule, end wear is a very lual process, but nevertheless the accuracy of end divisions should always be held under icion and should be checked from time to time

by testing against a rule which is known to b accurate. The possibility of error from this caus is, however, always present, and whenever prac ticable measurement should be taken not from or or other of the extreme ends of a rule, but from som intermediate division, e g from the 1 in. or th 1 cm. division mark.

Ivory and boxwood scales or rules undergo gradual shrinkage process with time, and are n to be relied upon for work where extreme accurac is required unless they are practically new or unle their accuracy is checked at frequent intervals

Steel Tapes.

Steel tapes are sometimes found to stretch a preciably, and for regular use in a workshop th must be checked for accuracy at frequent interva against a fixed standard dimension. such tes should be carried out at, or as near as practicab the same temperature each time that the steel ta is checked, to avoid any possible overestimate the inaccuracy, or, alternatively, any cancellati of the error, consequent on appreciable temperatu differences. Steel tapes which have been brok in use should never be repaired except by t actual makers, who, generally, have special metho and facilities for carrying out such repairs witho impairing the accuracy of measurement. In gener steel tapes when new are guaranteed by the mak to be accurate at a given tension, say 10 poun when supported over their entire length

pers.

he measuring edges of the jaws of slide calipers ıld be mınutely examıned from tıme to time to ertaın whether (1) the fixed and adjustable es are truly parallel, the one to the other through- their extent, and (2) the edges are truly straıght oughout their extent Rough usage on pieces vork may ın time produce wear on the measuring es, and the instrument ıs then useless for accurate k and should be sent to the makers for repaır.

he lockıng screws of slıde calipers and the contact faces between the adjustable edge and the body the ınstrument should be examıned from time tıme. Too heavy a hand in lockıng the adjust- e edge on the body of the instrument will cause essive wear on the contact surfaces, and this, turn, wıll tend to gıve inaccuracy of results. e slıdıng contact between the adjustable portion l the body of the instrument should be such that re is definite friction between the movıng parts t not sufficient frictıon to cause undue wear on the bbing surfaces.

The ordinary patterns of inside and outside ipers are now generally made with the joınt med with a screw threaded into a nut or stud. nsion on the point can thus be varied at will, d a uniform degree of friction of any desired ount can be obtaıned to suit the individual needs the user. The surface of the points should be amined at frequent intervals to avoid usıng the strument when there are burrs or indentatıons the measurıng points. Needless to say, such

scoring of the measuring points should never occur with proper usage, but neglect and rough handling may be, and unfortunately frequently is, their lot, hence the precaution of frequent examination is a wise one.

Combined inside and outside calipers are intended to give the same measurement at the points of both the inside and outside calipers; they can be relied upon in general to do this when new, but as they are generally used to a greater extent as either inside or outside calipers, frequent examination and checking is necessary to ensure that one set of points is not becoming more worn than the second pair of points. Their accuracy in giving identical measurement at both sets of points should always be under suspicion, and examination and checking of their accuracy must be carried out at regular intervals.

The special fittings of some calipers, such as screw thread adjustment (see p 53) need particular attention from time to time. The accuracy of fit between the fine adjustment screw and its nut, and the absence of wear between these parts, is an important feature as regards the accuracy and reliability of instruments of this class.

Micrometer Calipers.

Micrometer calipers in their various forms are particularly liable to damage from rough handling The fixed anvil and the end of the moving spindle are the points between which measurement is made, and a certain amount of wear on these surfaces is

ɿitable with time and use. In some makes of ɪruments of this class the anvil is made to be ustable in relation to the frame of the instrument compensate for wear on the measuring surfaces ; l in other makes the base or zero line is carried a friction sleeve placed over the barrel in relation which it is adjustable. With the latter type of ɪrument adjustment for wear is obtained as uired by rotating the friction sleeve on the rel until the line on the sleeve coincides with the ɔ line on the thimble.

nstruments which fail to give consistently urate results on repeated tests of a known dimen- ı should be scrapped ruthlessly , they are of no to the mechanic and are a hopeless impediment accurate workmanship.

'e Gauges.

Vire gauges of reputable make are supplied in cially hardened steel The width of the notches equal to recognized standards of measurement pp. 62 *et seq*). Measurement of gauges inter- liate between any two accepted standards cannot letermined accurately by this means, and in such es it is necessary to determine into which notch work will pass and at which notch it will just pass. It follows that, in time, friction of the cles being measured tends to cause minute argement of some of the notches, so that the uracy of the gauge as regards a portion or the ɔle of its range is lost Wire gauges should refore be frequently and periodically checked,

and they should be instantly rejected for work when wear on any of the notches becomes evidenced. Instruments of this class cannot of course be adjusted and their replacement by new and accurate gauges at intervals is essential to good workmanship.

General.

The centring points of all such instruments as scribing calipers, and the points of scribing styles require attention from time to time. The points must of necessity be kept sharp and the metal of the points must be specially hardened Blunt points mean indefinite marking, and, therefore, inaccuracy on the work

With hinged and jointed instruments of all classes it is of great importance to see that the joint has the requisite degree of friction for the work involved. Too little friction may result in errors of measurement by slipping; too much friction involves possibilities of straining the instrument during setting, difficulty (and consequently error) in getting the precise adjustment, and excessive wear at the joints.

The greatest care must at all times be exercised in preventing accidental damage to the working edges of instruments of the straight edge, try square, and level protractor types. Such instruments must on no account be left on the working bench when not in use, neither should they be placed loosely with other tools in a box or drawer, but they should always be secured in a proper case or fitting where they are safe from accidental injury.

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CHAPTER VII

LIMITS AND FITS

eneral Considerations on Classes of Fits.

'ITH the exception of certain special cases, the iestion of "fits" and corresponding "clearances," id "limits" or "tolerances" concerns only cylin-ical work. Theoretically, a shaft which "fits" hole should have a diameter exactly equal to the ameter of the hole but in machine shop work, in most other branches of practical work, exacti-ide is only a relative term. The cost of finishing a irface increases rapidly as one imposes closer mits upon the accuracy of the dimensions of the iece, and the limits to which one should work in ractice affect materially the cost and efficiency of roduction and are determined by the purpose to e served. A perfectly cylindrical shaft in a per-ectly cylindrical hole of the same diameter would e free to slide or rotate. The shaft would, however, ouch every part of the hole and there would be no oom for a film of lubricant. For this reason, and ecause *perfectly* cylindrical shafts and holes can e neither produced nor maintained in service, an xact fit is not even theoretically desirable where liding or rotation of the shaft is required; there iust be some clearance to allow for irregularities f the surfaces, to make lubrication possible, and to revent "binding" of the surfaces. On the other and, if the shaft be required to drive or hold the

part in which it is inserted, the diameter of the shaft must be larger than that of the hole so that, whether the shaft be forced into the hole or whether the collar, flywheel, etc , be shrunk on to the shaft, there will be internal stresses in the two parts preventing relative motion between them In the theoretical case of the shaft, which is an exact fit in the hole, the two parts touch, but there is no force between them, other than that due to their own weight,* and motion of the shaft cannot be transmitted to the collar. In the practical case approximating as closely as possible to this theoretical case, there would be sufficient irregularity of surface and sufficient frictional grip to enable the shaft to carry the collar with it against small resistance, but not against any appreciable or well-defined resistance. Popularly speaking, the "exact fit" in question would be neither one thing nor the other—it would be too tight for running and too loose for driving.

From these general considerations it will be appreciated that a shaft and hole which are machined, as accurately as commercially possible, to the same diameter will have to be forced or driven together The force required to mate them will be small, and we may say that they are a "light driving fit." If

* If seizure occurs between the parts, as it may easily do if they are a very accurate fit, they become practically welded together The extent of such seizure is, however, indeterminate, the risk of its premature occurrence would make assembly practically impossible, and no reliance could be placed upon a seized contact for driving purposes. Except as a possible danger where a clearance fit is really required, seizure is here left out of consideration.

e shaft be appreciably larger than the hole we ıve a "heavy driving fit" or a "force fit," which "heavier," the greater the excess diameter of ıe shaft. For a "slidıng fit" or an "easy push ," the shaft must be definıtely smaller than the ɔle. For a "running fit" the shaft must be yet naller to provide for lubricatıon and to compensate r the bınding action of deflectıon ın the shaft. ccording to the clearance provided, we may have "close running fit" or a "slack running fit" or ven a "coarse clearance," and it is evident that a ıuch larger clearance must be provided in the earings of heavy machinery workıng in dirty tuations than in fine machines for precision work.

imits in Repetition Manufacture.

So far we have considered only the class of fit etween a single shaft and hole, but the question of mits and tolerances reaches its greatest importance here repetition manufacture is concerned. A single haft and hole can lıterally be "fitted" together to ny desired degree of closeness or slackness without eference to any outside consideratıon. On the other and, if it is desired that a nomınal 1 ın. shaft should t any one of thousands of 1 in. holes—produced ın ifferent shops and durıng a term of years—with a learance suitable for a given purpose, then it is vidently of vital importance what interpretation s placed upon standard sıze, and what amounts re allowed by way of tolerance for machinıng and learance for the service in question.

Bases for Specifying Limits.

The alternative bases on which it is possible t define limits and fits are: (1) The unilateral systen shaft basis ; (2) the unilateral system, hole basis (3) the bilateral system, shaft basis ; (4) th bilateral system, hole basis

In the unilateral system, shaft basis, the diamete of the shaft is taken to be a constant factor, differer classes of fit being obtained by varying the actua diameter of the hole of the nominal size concernec The first British Standard Report on systems fc limit gauges (B.E.S A. Report No. 27—1906) recom mended that the shaft be the constant membe but this recommendation was not generally adopte by the engineering industry. The main practica disadvantage of the " shaft basis " is that it involve a set of reamers for each nominal size of hol differing from each other in diameter by the amount of the limits for different classes of work. Th provision and maintenance of such reamers, differin only by some thousandths of an inch, are bot difficult and costly. On the other hand, whe working with a standard diameter of hole it i comparatively easy and inexpensive to turn shaft to the diameters required for various classes of fits.

" Tolerance " and " Allowance."

These terms, which are often misunderstood an confused, are defined as follows in the origina B.E.S.A. Report (No. 27) on Standard Limit Gauge for Running Fits—

Tolerance. A difference in dimensions prescribe

ı order to tolerate unavoidable imperfectıons of orkmanship

Allowance. A dıfference ın dimensions prescrıbed ı order to allow of varıous qualıties of fit.

BRITISH STANDARD LIMITS AND FITS

The new Britısh standard report on limits and ts (B.E.S.A. Report No 164—1924) recommends ıe adoption of the hole as the constant member, nd embodies a table of standard tolerances appro- rıate to holes of different sızes and different grades f workmanship, so that all holes on the same system ınilateral or bilateral) of the same nominal sıze and ıe same specıfied grade, will be interchangeable.

The prıncıpal difficulty ın standardızing tolerances n holes lies ın the fact that both the "unılateral" ystem and the "bilateral" system are used In ıe unilateral system the tolerance is in one dırection nly from the nomınal size and is generally posıtive, e. every hole ıs of nominal sıze or larger, and the ominal sıze ıs the low limit of the hole. In the ilateral system the tolerance extends in both irections—not necessarily in equal amounts—from ıe nomınal sıze ; the latter lies between the high nd low limits of the hole, so that holes in the ilateral system may be either of nominal sıze or naller or larger

For the complete tables issued by the British ngineerıng Standards Association and a detailed xplanation of their use, the reader must of course

refer to the report itself,* but the notes in tl following pages will serve as an introduction to tl subject.

At present, bilateral limit gauges are used mo extensively than unilateral limit gauges in th country, but an appreciable percentage of Britis users of the bilateral system have expressed the preference for the unilateral system, and tl tendency in standardization on the Continent ar in the United States is distinctly towards tl unilateral system.

It is therefore recommended by the B.E.S that the unilateral system be used in connectic with cylindrical mating surfaces in cases where does not conflict with predominating present pra tice. To allow for the fact that predominatu present practice will in some cases determine tl continued use of the bilateral system, the B.E.S. Report includes: (1) a table (abridged in Table X herewith) giving two sets of hole tolerances, base respectively on the unilateral and on the bilater systems; (2) a table of graduated shafts suitab for pairing with either the unilateral or the bilater holes (see Table XVII). These tables are giv both in British (inch) and metric (millimetre) uni so as to meet all requirements. All the table diagrams, and notes required for the use of eith of the systems, in either British or metric uni

* Obtainable from the B.E.S.A., 28 Victoria Street, S.W 1s. 2d. post free. Readers cannot be urged too strongly obtain this report and all the other B E.S.A. reports which be upon their work. In addition to stating the British Standar for materials, machinery, apparatus, etc., these reports conte most instructive explanatory notes and other information.

obtainable in the form of wall charts for drawing
;e or workshop use.

ing and Non-mating Surfaces.

efore proceeding further it should be explained ; in deciding upon the system of gauging and amount of tolerances to be employed, one must inguish clearly between "mating surfaces," e.g.)le and shaft, in which the inter-relation between surfaces in contact is the guiding feature, and)n-mating" surfaces in which only one surface to be considered.

'he B.E S.A recommendation in favour of the ateral system is restricted definitely to mating 'aces, because either unilateral or bilateral toler-es may be used for non-mating surfaces, the ice depending mainly on convenience in manu-ure. For example, if the article made tends to ome always bigger or always smaller, due to r of dies, the tolerance might well be unilateral, reas, if the dimensions are also dependent upon adjustment of the producing apparatus, such as 3, a bilateral tolerance may be preferable.

B.E.S.A. Standard Tables for Limits and Fits.

s already stated, these tables are here reproduced y in abbreviated form, but the particulars given enable the use of the tables to be understood the simplicity of the whole to be appreciated.

'able XVI gives the unilateral and bilateral limits olerance for holes. In the unilateral holes the limit of the hole is nominal size, i.e. there is no

TABLE XVI

British Standard Limits for Unilateral, Bilateral, and Oversize Holes

NOTE. All Dimensions except Nominal Sizes are expressed in *thousandths of an inch*

H = High Limit of Tolerance. L = Low Limit of Tolerance

The sign + or − below the symbols H and L indicates whether the limits are positive or negative

The use of the unilateral system as applied to cylindrical mating surfaces is recommended in cases where it does not conflict with predominating present practice

Size Multiplier	Nominal Sizes	Unilateral Holes								Bilateral Holes								Oversize Holes						Holes and Shafts for Non-Mating Fits	
-		*B.*		*U.*		*V.*		*W*		*K*		*X.*		*Y*		*Z*		*A*		*G*		*H*		*J*	
m	Inches	*H*	*L*	*H*	*L.*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*
		+		+		+		+		+	−	+	−	+	−	+	−	+	+	+	+	+	+	+	−
3	0 to 0 29	0 3	0	0 6	0	1 2	0	2 4	0	0 1	0 2	0 3	0 3	0 6	0 6	1 2	1 2	1 2	0 6	1 8	1 2	2 4	1 8	3 0	3 0
4	0 3 to 0 59	0 4	0	0 8	0	1 6	0	3 2	0	0 2	0 2	0 4	0 4	0 8	0 8	1 6	1 6	1 6	0 8	2 4	1 6	3 2	2 4	4 0	4 0
5	0 6 to 0 99	0 5	0	1 0	0	2 0	0	4 0	0	0 2	0 3	0 5	0 5	1 0	1 0	2 0	2 0	2 0	1 0	3 0	2 0	4 0	3 0	5 0	5 0
RANGE FACTOR, r	.	1	0	2	0	4	0	8	0	05	05	1	1	2	2	4	4	4	2	6	4	8	6	1 0	1 0

limit of tolerance and $L = 0$ for all cases. In bilateral holes, the nominal size lies between high and low limits, which are positive and ative respectively. Provision is made for four ıdard grades of workmanship for holes, the *B* ılateral) and *K* (bilateral) holes representing the st accurate grade; the *U* and *X* holes repreting those most commonly employed; and the es, *V*, *W*, *Y*, and *Z* having larger tolerances. meet exceptional conditions, oversize holes *A*, *G*, *H* are provided, these are common to both the lateral and the bilateral systems, and have two itive limits of tolerance, i.e. the low limit of the e is larger than the nominal size. Finally, yet er limits (*J*, Table XVI) are provided for the es and shafts which are not required to mate.

'able XVII gives the recommended limits of rance for a standard series of graduated shafts, able for pairing, with either the unilateral or teral holes. This table, which is common to unilateral and bilateral systems, provides for a es of 14 different fits with reference to any ticular hole, by progressively changing the position of the tolerance in relation to the nominal . The actual value of the tolerance remains hanged for all shafts from *F* to *M* inclusive, se shafts being of the same grade of workman- as a *B* hole (see Table XVI) The remaining fts, *Q* to *TT*, are given increasing tolerances ause they are all considerably undersize and efore provide increasing amounts of clearance n assembled in any hole.

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TABLE XVII—BRITISH STANDARD LIMITS FOR STANDARD SHAFTS

For Use with either Unilateral, Bilateral or Oversize Holes

Note. All Dimensions except Nominal Sizes are expressed in *thousandths of an inch*

See also note below heading of Table XVI

Size Multi-plier	Nominal Sizes	*F.*		*E*		*D.*		*C*		*B*		*K.*		*L*		*P*		*M.*		*Q*		*R*		*S*		*T*		*TT*	
m	Inches	*H*	*L*	*H*	*L*	*H*	*L*	*H.*	*L*	*H.*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L.*	*H*	*L*	*H*	*L*	*H*	*L.*	*H.*	*L.*
		+	+	+	+	+	+	+	+	+		+	−		−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
3	0 to 0 29	1 2	0 9	0 9	0 6	0 6	0 3	0 4	0 1	0 3	0	0 1	0 2	0	0 3	0 2	0 5	0 3	0 6	0 5	0 9	0 9	1 5	1 5	2 4	2 4	3 6	3 6	6 0
4	0 3 to 0 59	1 6	1 2	1 2	0 8	0 8	0 4	0 6	0 2	0 4	0	0 2	0 2	0	0 4	0 2	0 6	0 4	0 8	0 6	1 2	1 2	2 0	2 0	3 2	3 2	4 8	4 8	8 0
5	0 6 to 0 99	2 0	1 5	1 5	1 0	1 0	0 5	0 7	0 2	0 5	0	0 2	0 3	0	0 5	0 3	0 8	0 5	1 0	0 8	1 5	1 5	2 5	2 5	4 0	4 0	6 0	6 0	10 0
Range Factor, *r*		4	3	3	·2	2	1	15	05	1	0	·05	05	0	1	05	15	1	2	15	3	3	5	5	8	8	1 2	1 2	2 0

ables XVI and XVII as here given cover only inal sizes from 0 to 0·99 in. The corresponding es in the B.E.S A. Report extend up to 25 in. mm) and can be extended further by aid of ors which are explained below. The nominal are specified in ranges, the length of each e being such that at each change of range the ance increase on U and X holes is 2 tenusandths of an inch (0·0002 in.).

Multipliers and Range Factors.

ie size multipliers m and the range factors r, es XVI and XVII, enable the limit values in e tables to be virtually "carried in the head." limit values are obtained by multiplying ther the appropriate values of m and r, odd ten-thousandths being omitted from the ucts in which they occur.

AMPLE.—For a nominal 0·5 in. U hole (Table XVI), 4 and $r = + 0{\cdot}2$ and 0; hence the standard (unilateral) are $+ 0{\cdot}8$ and 0. For a Y hole of the same nominal $m = 4$ and $r = + 0{\cdot}2$ and $- 0{\cdot}2$; hence the standard eral) limits are $+ 0{\cdot}8$ and $- 0{\cdot}8$.

iough Tables XVI and XVII give all the values they include only three values for m. The e of m for any other size of hole is calculated ollows—

D = nominal size of hole in inches, then m is such that—

$$m\ (m - 1) > 20\ D \geqq (m - 1)\ (m - 2).$$

expression is solved very easily.

AMPLE.—Suppose that the nominal diameter of the hole aft is $3\frac{3}{4}$ in., then $20D = 20 \times 3\frac{3}{4} = 75$, and we have to

find two consecutive numbers, m and $(m - 1)$, the product of which exceeds 75, whilst the product of the next lower consecutive numbers $(m - 1)$ and $(m - 2)$ is equal to or less than 75 In other words, if we have three consecutive numbers, A, B, C, such that $20D$ is intermediate between $A \times B$ and $B \times C$, then m equals A, the largest of these three numbers.

In this case $10 \times 9 = 90$, which is greater than $20D$, and $9 \times 8 = 72$, which is less than $20D$, hence $m = 10$.

For a W hole, $r = + 0{\cdot}8$ and 0, so that the limits $(m \times r)$ are $+ 8$ and 0, whilst for a K shaft, $r = + 0{\cdot}05$ and $- 0{\cdot}05$, hence the limits are $+ 0{\cdot}5$ and $- 0{\cdot}5$.

Standard Fits.

The basis of the B.E.S.A. tables being a hole basis, the limiting dimensions of any hole of a particular quality and size remain unchanged, and varieties of fit are obtained by varying the actual dimensions of the shaft.*

Table XVIII gives typical examples of the fits thus obtained between standard shafts (Table XVII) and U and X holes (Table XVI), these holes being chosen for the purpose of numerical examples, because the tolerances on them are those most commonly employed The limits of fit resulting from the assembly of the standard shafts in any of the other holes specified, are determined by taking the algebraic difference between: (a) the largest hole and smallest shaft, (b) the smallest hole and largest shaft. The results thus obtained are the upper and lower limits of the fit, and three cases must be distinguished—

1. If the smallest hole be greater than the largest shaft we have a *clearance fit.*

2. If the largest hole be smaller than the smallest

* The Association recognizes that exceptions to this rule are necessary in certain classes of work.

TABLE XVIII

TYPICAL EXAMPLES OF BRITISH STANDARD FITS OF STANDARD SHAFTS IN *U* AND *X* HOLES

NOTE. All Dimensions except Nominal Sizes are expressed in *thousandths of an inch*

$+$ = Clearance $-$ = Interference

The upper figures in each square represent the minimum, the lower figures the maximum, limit of fit

Nominal Sizes	Standard Shafts in Unilateral *U* Holes						Standard Shafts in Bilateral *X* Holes					
Inches	*UF*	*UE.*	*UD*	*UM*	*UQ*	*UTT*	*XF*	*XE*	*XD*	*XM*	*XQ*	*XTT.*
0 to 0 29	−1 2 −0 3	−0 9 0	−0 6 +0 3	+0 3 +1 2	+0 5 +1 5	+ 3 6 + 6 6	−1 5 −0 6	−1 2 −0 3	−0 9 0	0 +0 9	+0 2 +1 2	+ 3 3 + 6 3
0 3 to 0 59	−1 6 −0 4	−1 2 0	−0 8 +0 4	+0 4 +1 6	+0 6 +2 0	+ 4 8 + 8 8	−2 0 −0 8	−1 6 −0 4	−1 2 0	0 +1 2	+0 2 +1 6	+ 4 4 + 8 4
0 6 to 0 99	−2 0 −0 5	−1 5 0	−1 0 +0 5	+0 5 +2 0	+0 8 +2 5	+ 6 0 +11 0	−2 5 −1 0	−2 0 −0 5	−1 5 0	0 +1 5	+0 3 +2 0	+ 5 5 +10 5

shaft we have an *interference fit*, i.e obstruction, the amount of which is even greater with the smaller holes and larger shafts.

3. The term *transition fit* covers cases intermediate between (1) and (2), i.e. cases in which the limits admit of either clearance or interference fits being obtained.

EXAMPLES.—(i) Suppose that an *E* shaft, nominally of ½ in diameter, be used in a *U* hole, what are the limits of fit?

From Tables XVI and XVII the largest hole is + 0·8 thousandths of an inch oversize, and the smallest shaft is also + 0·8 thousandths oversize, the allowance between these two is therefore 0·8 – 0·8 = 0, i e an exact fit On the other hand, the limit for the smallest *U* hole is 0, and that for the largest *E* shaft is + 1·2; the difference is 0 – 1·2 = – 1·2 thousandths, the shaft being the bigger The limits of fit in the case considered are thus – 1·2 to 0 (see *UE*, Table XVIII), and the fit is always an "interference fit."

(ii) Proceeding similarly, it will be found that, for the same nominal size—

(*a*) A *D* shaft in a *U* hole gives fits from – 0·8 to + 0·4, i.e. a "transition fit"

(*b*) An *M* shaft in a *U* hole gives fits from + 0·4 to + 1·6, i e a "clearance fit"

(*c*) An *E* shaft in an *X* (bilateral) hole gives fits from – 1·6 to – 0·4, i.e. an "interference fit"

(*d*) A *TT* shaft in an *X* hole gives fits from + 4·4 to + 8·4, i.e. a "clearance fit," and a coarse one at that.

The effect of transferring any standard shaft from a bilateral hole to a unilateral hole, is to increase the clearance or reduce the interference, i.e. to make the fit easier. An example of this may be seen by comparing Examples (i) and (ii *c*) above.

Specifying Fits.

Even to-day it is not uncommon to find drawings dimensioned throughout with single dimensions. For example, a shaft and bearing may be marked

in. diameter, but it is clear, from what has already een said in this chapter, that the actual diameters ust differ by, say, 0·005 in to provide for a running , with suitable clearance for lubrication, etc.

If the drawing bears only a single dimension it is ft to the discretion of the machinist or fitter to ecide what clearances should be provided and here. Obviously it is better, from every point of ew, to specify all the limits on the drawing itself.

When the exact nature of a fit has to be named is recommended by the B.E.S.A. that the symbols ' the hole and shaft be used in combination, e.g *B*, and marked on the assembly drawing in this rm The drawing of the hole and the drawing of ie shaft can then be marked, in combination with ie nominal size, say ½ in. *U* for the hole, and in. *B* for the shaft, meaning in this instance iat the hole is to be within the limits 0·5008 in nd 0·5000 in , and the shaft between the limits ·5004 in and 0·5000 in. (see Tables XVI and XVII). 'his particular combination would include clearance ts and interference fits, i.e. it would be termed a ansition fit.

If preferred, the numerical values of the limits, istead of the corresponding symbols, may be pecified on drawings.

Though such terms as "driving fit," "push fit," nd "running fit" have no well-defined meaning, hey are nevertheless very descriptive, and to many ersons they convey an idea of the quality of a fit iore vividly than would a numerical statement of he clearances. The actual value of the clearances

in a "running fit" is naturally greater for a large shaft than for a small one, but Table XIX shows values of the range factor r corresponding to various classes of fit as described in workshop terms. On multiplying the appropriate value of r by the value of m for the nominal size of hole and shaft concerned (this value of m being calculated as already explained), we obtain the numerical value of the limits for the nominal size and class of fit in question.

TABLE XIX

VALUES OF "RANGE FACTOR" r CORRESPONDING TO VARIOUS CLASSES OF FITS IN UNILATERAL U HOLES AND BILATERAL X HOLES

NOTE The actual limits in thousandths of an inch = $m \times r$, where m is the "size multiplier," calculated as explained on page 139

Description of Fit		Value of r Unilateral	Value of r Bilateral
Clearance Fits	Coarse clearance	+ 1·2 to + 2·2	+ 1·1 to + 2·1
	Extra slack running	+ 0·8 to + 1·4	+ 0·7 to + 1·3
	Slack running	+ 0·5 to + 1·0	+ 0·4 to + 0·9
	Normal running	+ 0·3 to + 0·7	+ 0·2 to + 0·6
	Close running (2)	+ 0·15 to + 0·5	
	" " (1)	+ 0·1 to + 0·4	
	Easy slide	+ 0·05 to + 0·35	
	Slide or easy push	0 to + 0·3	
Transition Fits	Push	− 0·05 to + 0·25	
	Light keying	− 0·1 to + 0·2	
	Medium keying	− 0·15 to + 0·15	
	Heavy keying	− 0·2 to + 0·1	
	Extra light drive	− 0·25 to + 0·05	
Interference Fits	Light drive	− 0·3 to 0	
	Heavy drive	− 0·4 to − 0·1	
	Force	− 0·5 to − 0·2	

EXAMPLES —(1) For a $3\frac{1}{2}$ in. shaft, $20D = 70$ and $m = 9$,* and from Table XIX r for a normal running fit = + 0·3 to + 0·7 for the unilateral system and + 0·2 to 0·6 for the bilateral system Hence the actual limits would be ($m \times r$) or + 2·7 to + 6·3 thousandths of an inch for the unilateral U hole, and + 1·8 to + 5·4 thousandths for the bilateral X hole. As already

* $9 \times 8 = 72 > 8 \times 7$, see page 139.

ted, changing from the bilateral to the unilateral system ults in an easier fit

'ii) What are the limits for a $\frac{3}{4}$ in (nominal) shaft which is quired to be a push fit in a unilateral *U* hole ?

In this case $m = 5$ and, from Table XIX, $r = -0{\cdot}05$ to $+ 0{\cdot}25$, nce the limits $(m \times r)$ are $-0{\cdot}25$ to $+ 1{\cdot}25$ thousandths of an h or, say, $-0{\cdot}2$ to $+ 1{\cdot}3$ thousandths. These limits correspond the use of a *K* shaft in a *U* hole.

orkshop and Inspection Gauges.

Limit gauges are used to ensure that any given mension is within the tolerance specified for the ass of work to be produced. As already explained hapter III), in the case of cylindrical work, ese gauges may be either double male gauges, e end of which must enter, and the other end of uch must not enter, the hole to which it is applied ; they may be either two-ring or two-gap gauges, e of which must pass over, and one of which ust not pass over, the plug or male piece to which ey are applied

Workshop gauges are used in the course of manucture to ensure that no work falls outside the nits of fit specified by the standard tables adopted. ie allowance for wear and abuse which is made the workshop gauges reduces the extent of the escribed tolerances, so that work which is within e standard limits may sometimes be rejected by e workshop gauges.

Inspection gauges are used to secure that the mensions of pieces are such that they can be cepted under a contract, and that no work which mplies with the specified dimensions is rejected. ie tolerances on inspection gauges are, therefore, tside the limits of fit specified by the standard

tables, and work may be accepted by such which exceeds the specified limits by a comparable with the tolerances on the gaug

For obvious reasons it is most importa gauges be measured very accurately, otherw advantages and possibilities of a stand system of limits and fits cannot be realized. inaccurate gauges the tolerance actually g the work may be either appreciably greater than is intended. The use of such gauges, t lack of means to measure them with su accuracy, might result, if the error were direction, in the work having to conform tolerances than those intended, thus raising of production; whilst, if the error were other direction, the work would have a tolerance than that considered desirable, prejudice of the resulting fit. The use of slip to check limit gauges is illustrated in Figs 41

In the interests of uniformity it may be that the new limits specified by the B.E.S be generally adopted, but the Newall system has been employed so widely, is sure to re use for some time to come. This need lea confusion, for any work machined to the limits (see below); will, in general, be wit new B.E.S.A. limits, or so nearly so, that no p difficulty will be introduced

Newall Limits.

The system of limits for various classes developed by the Newall Engineering Co

hole basis, and the allowances in this system ·y be summarized as in Table XX

TABLE XX

ALLOWANCES FOR VARIOUS CLASSES OF FITS
(HOLE BASIS)

As laid down by the Newall Engineering Co

E The minimum diameter of the hole is accurately its nominal size
The values for limits and tolerances are in *ten-thousandths of an inch*

minal meter ches	FORCE FITS			DRIVING FITS			PUSH FITS.		
	Limits		Toler-ance	Limits		Toler-ance	Limits		Toler-ance
	High	Low		High	Low		High	Low	
to ¼	+ 10	+ 5	5	+ 5	+ 2 5	2 5	− 2 5	− 7 5	5
) 1 .	+ 20	+ 15	5	+ 10	+ 7 5	2·5	− 2 5	− 7 5	5
to 2	+ 40	+ 30	10	+ 15	+ 10	5	− 2 5	− 7·5	5
to 3	+ 60	+ 45	15	+ 25	+ 15	10	− 5	− 10	5
to 4	+ 80	+ 60	20	+ 30	+ 20	10	− 5	− 10	5
to 5 .	+ 100	+ 80	20	+ 35	+ 25	10	− 5	− 10	5
to 6 .	+ 120	+ 100	20	+ 40	+ 30	10	− 5	− 10	5

rew Gauges and Limits.

The questions of screw thread measurement, screw uges, and errors in screw threads are too complex : any useful discussion to be attempted in the ace here available, but the reader who has astered the contents of this volume will be in a sition to study the precise measurement of screw reads, and he should undoubtedly undertake this teresting and important work. The admirable ıblications issued by the National Physical ıboratory will be found most instructive.

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